Title: Formalizing the Blue Economy: Residential Solar PV Financing Model

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List of Acronyms

CSI	California Solar Initiative – CSI
CDM	Clean Development Mechanism – CDM
CMO	Collateralized Mortgage Obligations – CMO
CPR	Conditional Prepayment Rate – CPR
CSP	Concentrating Solar Power –CSP
CEFIA	Connecticut Clean Energy Finance and Investment Authority – CEFIA
DSIRE	Database for State Incentives for Renewables & Efficiency – DSIRE
ESPC	Energy Saving Performance Contracts – ESPC
ESP	Equity Solar Programs – ESP
EPIA	European Photovoltaic Industry Association – EPIA
FERC	Federal Energy Regulatory Commission – FERC
FHLBB	Federal Home Loan Bank Board – FHLBB
FHA	Federal Housing Administration – FHA
FIT	Feed In Tariff – FIT
FIRST	Financing Initiative for Renewable and Solar Technology – FIRST
GW	Gigawatt – GW
GNMA	Government National Mortgage Association – GNMA
IPP	Independent Power Producers – IPP
IRR	Internal Rate of Return – IRR
IRS	Internal Revenue Service – IRS
IEA	International Energy Agency- IEA
ITC	Investment Tax Credit – ITC
kW	Kilowatt – kW
LCOE	Levelized Cost of Energy – LCOE
LTV	Loan To Value – LTV
MW	Megawatt – MW

MBS	Mortgage Backed Securities – MBS
MPT	Mortgage Pass-Through – MPT
NREL	National Renewable Energy Laboratory – NREL
NEF	New Energy Finance – NEF
OTC	Over The Counter – OTC
PV	Photovoltaic – PV
PVHS	Photovoltaic Home System – PVHS
PAM	Pledged Account Mortgages – PAM
PPA	Power Purchase Agreement – PPA
PACE	Property Assessed Clean Energy – PACE
RPS	Renewable Portfolio Standard – RPS
RESNET	Residential Energy Services Network – RESNET
ROM	Roll Over Mortgages – ROM
SEFA	Solar Energy Financing Authority – SEFA
SREC	Solar Renewable Energy Certificate – SREC
SUV	Sports Utility Vehicle – SUV
SSVEC	Sulphur Springs Valley Electric Cooperative – SSVEC
SAM	System Advisory Model – SAM
TEP	Tucson Electric Power – TEP
US	United States of America – US
USD	United States Dollar – USD
DOE	US Department of Energy – DOE
EIA	US Energy Information Administration – EIA
EPA	US Environmental Protection Agency – EPA
Wp	Watt *Ponta* – Wp

Introduction

Solar photovoltaic (PV) technology is the focus of this work, specifically decentralized solar PV energy generation. Hence, this study examines technological advancements in energy production and develops two financial models to assist with implementation of such technology. In the chapters that follow I will validate a scenario where deployment of capital toward large-scale implementation of PV technologies can benefit investor, borrower and community.

During the 19th and 20th centuries in the United States of America (US), retail banks, the automotive industry as well as credit unions (saving and loan, thrifts) created new and innovative ways in which capital would be reallocated to improve the community, advance technology and cater to investor needs. Financial models such as the residential mortgage, auto loan and later auto lease were created so that ever more Americans could begin to subscribe to what is today known as "the American dream"[1]—owning a home with a two-car garage. The common blue-collar worker could never own a home or automobile until the aforementioned industries created a market, a standardized financial instrument and a regulator (the federal government) with the authority to protect investor, borrower and community. The residential mortgage and car loan or lease allowed individuals to own today what would have taken them a decade or more of savings. Finance, or rather the management of capital as it affects the public and private sector, served to fulfill such needs and desires. These new and innovative forms of finance facilitated the development of a new economy and society as compared to Communist or planned economies and societies.

A new financial instrument that would support the ownership of solar PV on a residential scale can reallocate capital from vintage to new technology. This reallocation would improve the community while simultaneously safeguarding retail banks and credit unions as residential mortgages did when they were first introduced as financial instruments. Although this work does not focus on residential mortgages and car loans, I will draw a parallel between these financial models and the one I am proposing. Both residential mortgages and car loans are financial innovations of the past 100 years. When Henry Ford invented the internal combustion engine, the automobile and eventually the modern day production line economy, who could have imagined that a century later, that single invention could shape current life styles, economy and society at large? Today we enjoy the luxury of being able to rent, buy, lease or even zip a car.[2] We do not have to pay for the car immediately nor do we ever have to pay the full market price if we do not desire to own the car. The same way that the United States and Europe progressed from a horse-and-buggy economy to an automotive economy, I would like to propose a financial model that would be a step in the evolution from a centralized fossil fuel electricity generation to a decentralized renewable energy generation economy. The value of a PV system for a residential home is equal to, if not less than, most Sports Utility Vehicles (SUV), lower than the value of an average middle-class American home. Therefore, I propose the creation of a financial instrument that will allow American and/or Portuguese homeowners to acquire a PV Home System (PVHS) as easily as they would a new car or home.

The PVHS, which I will continuously refer to in this paper, is a standard solar photovoltaic system that conforms to the size of the owner's home. By this I mean that the physical space on the roof of the property, and the structural capacity of said roof to bear the

[1] James Turslow Adams first coined the term "American dream" in his book The Epic of America in 1931
[2] "*Zipcar is the world's largest car sharing and car club service. It is an alternative to traditional car rental and car ownership.*" Accessed on December 8, 2012: http://www.zipcar.com/

load of the PVHS, would determine the size of the system. The PVHS would consist of the components referenced in Appendix 10 and should be considered to be grid- connected. Such solar photovoltaic systems are sold, installed and maintained by companies such as Efacec Renewables in Maia, Portugal or SunRun in San Francisco, USA. In Appendix 9 the reader will find details on a specific PVHS and all the components and costs for the PVHS as prepared by Efacec Renewables.

I suggest that homeowners should be able to own the system just as they would a car or a home through a standardized financial product. I will call this credit a PVHS Loan. The PVHS Loan is a standard low-interest loan with a 10- to 30-year maturity, only valid for the purchase of a PVHS. The debtor has the option of creating a sinking fund using his or her energy savings and will pay interest monthly to the creditor. If the debtor becomes delinquent on the loan's payments, the PVHS Loan will become a PVHS Mortgage. Consequently, the PVHS Mortgage would cover the interest and principal through monthly payments made by the homeowner. The homeowner would purchase the PVHS, but would ordinarily continue to pay his or her energy bills. A third party would collect the energy payments from the homeowner and aggregate all the benefits offered to PHVS owners. The third party would then pay down the mortgage on a monthly basis using the benefits offered for the production of renewable energy as well as the savings incurred by the system. The payments would be varied, but have a minimum given the benefits and savings. The proposed financial models differ from current models as the financing is sourced from the private sector, it is done on a micro scale and ownership of the PVHS belongs to the homeowner. The last point is important as currently the lessor or a third party is the entity receiving the benefits (from the local power company, State, Federal or any other authority which concedes benefits.)

1.1 Problem Statement

The large-scale financing of PVHS has not been fully developed for Europe and/or North America. Hence, there is a dearth of empirical evidence to support the claim that these systems are beneficial to investors and consumers. The investigation of how PVHS financing will be done and how to include those who would like to participate is what will be studied herein. A specific PVHS (Appendices 9 & 10) has been chosen based on the average size of a US and/or Portuguese home; current market prices offered by American and Portuguese home energy system installers are reported herein as the cost. This information will be used to obtain data-driven conclusions about the relative costs and savings, which might be incurred if individuals install a specific PVHS in their home. Therefore, lenders can begin to create a market for these systems, thus diversifying their offering and preventing the moral hazard that many mortgage lenders faced in the past two decades.

There are a variety of goods and services for sale in the global marketplace. Such goods and services are used to increase the consumer's productivity, utility or pleasure, to name just a few. Some of these goods and services are capital intense, which makes owning or acquiring them impossible for a majority of the population. The cost of a PVHS is as inaccessible to most individuals as the cost of a new home or car. In the US, to alleviate this situation, public solutions are being offered to those individuals who would like to own their own PVHS. I advance the idea that private institutions can adopt a new financial model, thereby allow a greater number of individuals to own their own PVHSs.

First, I will deconstruct the problem of individual ownership of power generation, transmission and consumption and use the example of residential mortgages to demonstrate how the evolution of this financial model can be applied to new technological advancements. I will also show how the PVHS financial models can assist financial institutions to avoid unnecessary risks and contribute to economic growth.

Second, to better understand the viability of PVHS, I will quantify the real costs and benefits of engaging such a system in Portugal and the United States of America. As there is no generic PVHS, I will use the PVHS described in Appendices 9 & 10 and quantify the costs and benefits of said system functioning in Lisbon, Portugal and San Diego, California.

Third, I will illustrate how through manipulating the current mortgage-financing model we can provide individuals with ownership of their own PVHS, and the private sector can benefit while avoiding the catastrophic repercussions that have agitated international financial markets in the past five years.

1.1.1 Research Questions

- 1) What is the cost effectiveness of decentralized solar PV energy generation? (That is, what are the costs and benefits of decentralized solar PV energy generation from the point of view of commercial credit markets and what is the cost effectiveness compared to continuing to finance a traditional power generator?)

- 2) What are the current business models for PVHSs? (That is, can these models be adapted? Is there opportunity for new models better suited to PVHS adoption? Who will be the key players involved in the value chain? What incentives or hindrances currently exist? Can ownership change? Where is risk being allocated? What are the advantages or disadvantages of the discussed business models?)
- 3) What are the financing alternatives that would be congruent with the new PVHS business model? (That is, how do these financing alternatives relate to current market conditions? What metrics would be used to calculate the size and volume of the market for decentralized PVHSs? How are the risks weighed?)
- 4) Would it be possible to bundle a large number of PVHSs into partnerships so as to securitize them? (That is, what are the possible innate advantages and disadvantages of securitizing PVHS partnerships? Could this new scheme mimic mortgage securitization?)

From the above research questions, this thesis endeavors to contribute to further understanding of renewable energy in evolving credit and risk markets. Through the selection of San Diego, California and Lisbon, Portugal, we can study the impact on a microeconomic, individual scale rather than a macroeconomic, utility-sized scale of a PVHS in two geographies with economically and climatically similar variables. These two cities will serve as case studies for the PVHS described in Appendices 9 & 10. The financial models suggested detail how society through individual approaches can begin to own and operate private energy production and transmission systems. Also, this paper will add to the general body of research that has been created in the area of renewable energy cost efficiency, financing and specifically on how the private sector can begin to engage the individual who is interested in owning a PVHS but believes that the upfront capital investment is too great. Finally, this work will provide insights as to how these "micro" PVHS loans can be repackaged and sold to larger institutions and investors thereby providing a tenable flow of capital to lenders who understand the risks.

1.2 Outline

This thesis' four chapters and their subsections are depicted in Figure 1. A matrix and several figures and appendices have been incorporated into this work so that the reader may follow the two specific PVHS cases (Lisbon, Portugal and San Diego, California) of solar photovoltaic technology financing for individuals who own a residence. I suggest reviewing the appendices first so that as various concepts are developed, the reader may reference the appropriate material. The Introduction Chapter is meant to prepare the reader for the Literature Review & Background Chapter, which details solar PV technology history, applications, cost effectiveness, current business and financing models. Next, the Methodology and Discussion and Main Conclusions will answer questions of viability for the two contributing geographies. Recommendations point to potential business and financial models. Finally, future research needs to examine a variety of regulatory-specific benefits that are appropriate to the two geographies, and take into consideration how the models might be scaled up to local commercial and non-residential institutions.

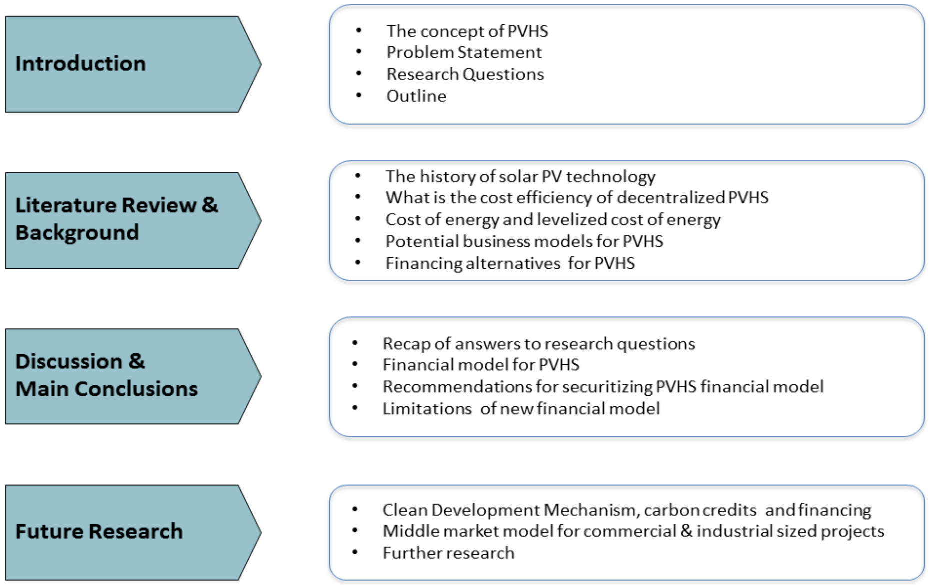


Figure 1: Systematic Outline of Formalizing the Blue Economy Working Paper.
Source: David N. Pereira

Literature Review & Background

2.1 Solar Energy

In 1839 French physicist A.E. Becquerel began to experiment with the photovoltaic effect. Forty-four years later the first solar cell was constructed by Charles Fritts with an energy conversion efficiency of around 1%.[3] Energy conversion efficiency is a measure of the amount of energy produced in proportion to the amount of energy consumed. In 1954, Gerald Pearson, Calvin Fuller and Daryl Chapin, following the work of Russell Ohl, created what is known today as the silicon solar cell at Bell Laboratories. Their invention reached an energy conversion efficiency of up to 6%.[4] The estimated cost of their solar cells in 1954 was between 250—290 USD/watt as compared to 2—3 USD/watt from a coal-fired power plant.[5] A coal-fired power plant has an energy conversion efficiency of around 28% as compared to crystalline solar panels that are 7% to 18% efficient, depending on the technology. Improvements in photovoltaic technology have brought efficiencies up to 43.5% and the price of the silicon solar cell to less than 1 USD/watt with wholesale prices well under 2 USD/watt (see Figure 2).[6]

[3] Perlin, John
[4] Perlin, John
[5] Perlin, John
[6] Depending on market regulations and tax consideration.

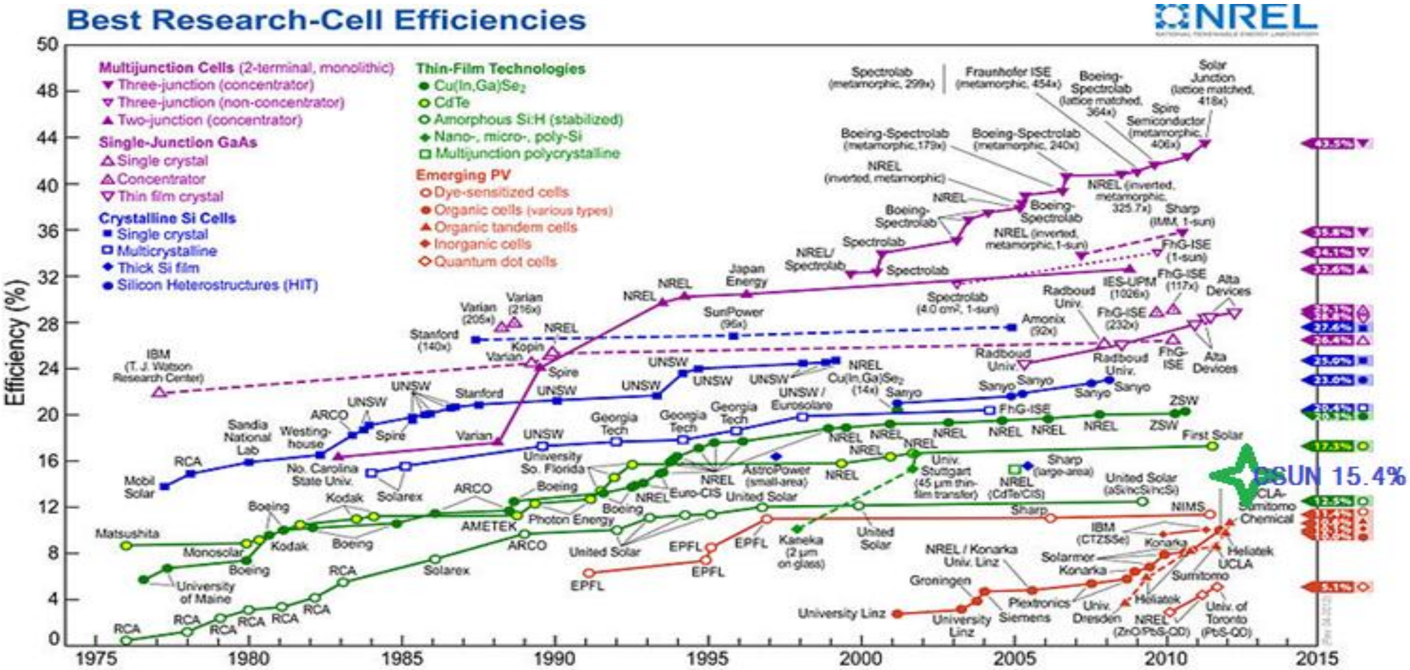


Figure 2: Energy Conversion Efficiencies of Competing Solar Cell Technologies 1976 through 2012.

Energy conversion efficiency is defined as the efficiency of a device that converts one energy form into another. For example, a coal-fired power plant has an energy conversion efficiency of around 28% as compared to crystalline solar panels (in blue) that are 13% to 27.4% efficient. Improvements in photovoltaic technology have brought efficiencies up to 43.5%. The green star on the right represents the CSUN crystalline Si solar cell that will be discussed in this paper.

Source: L.L. Kazmerski (April 2012). National Renewable Energy Laboratory (NREL), Golden, CO.

Solar PV technology has made great advances in the past 40 years. However, there is a large debate whether it has reached the point whereby it would be equal to or cheaper for the average US or Portuguese citizen to adopt given alternatives. The relative value between consuming solar PV or an alternative energy that is generated and transmitted through an electrical grid is known as grid parity. Grid parity for solar PV has already been achieved in some parts of the world, in part because the cost of generating and transmitting energy to remote or rural areas is prohibitive. According to the European Photovoltaic Industry Association, Portugal has a 50% probability of PV grid parity in 2013 and 90% by 2014.[7] For example, a small island in Hawaii would spend more on diesel fuel to power its generators as compared to a solar PV system.

The International Energy Agency (IEA) has stated that solar energy provides an affordable, inexhaustible and clean source of energy that can increase a country' energy security. Energy security is achieved through reliance on an indigenous, inexhaustible and independent resource such as solar PV. Moreover, the IEA has confirmed that solar energy enhances global sustainability, reduces global pollution, lowers the costs of mitigating climate change globally, and keeps fossil fuel prices lower than otherwise.[8] The energy conversion efficiency of solar cells has been rising rapidly in the past forty years as depicted in Figure 2. This rise in efficiency has led to a reduction in costs as new manufacturers enter the market.

The European Photovoltaic Industry Association (EPIA) at the close of 2010 estimated that global installed PV capacity was close to 40 gigawatts (GW), in other words in 2010 the cumulative global PV capacity installed and generating electricity was 40 GW. It is

[7] PV Parity Project.

[8] International Energy Agency Report: Solar Energy Perspectives.

estimated that an additional 27.4 GW of new PV capacity was installed in 2011, which would make total global installed PV capacity 67.4 GW at the beginning of 2012. This translates to 80 billion kWh or enough to power 20 million European households for one year. EPIA and NREL predict that total installed PV capacity will reach 100 GW by January 2013. Since 2005 government subsidies in Europe have tended to promote grid-connected PV rather than off-grid systems. Market evolution has been highly susceptible to the dynamic of subsidies offered, stages of market maturity, demand for particular applications, and economic and cost factors. The countries with the largest percent of grid-connected PV in 2011 were Germany, Italy, Japan, Spain and the US (see Figure 3). Alternatively, world leaders in installed PV have historically been Sweden, Turkey, Mexico, and Norway, all of which have PV market compositions dominated by off-grid systems. According to the EPIA, most of these off-grid systems are residential rather than industrial or agricultural.

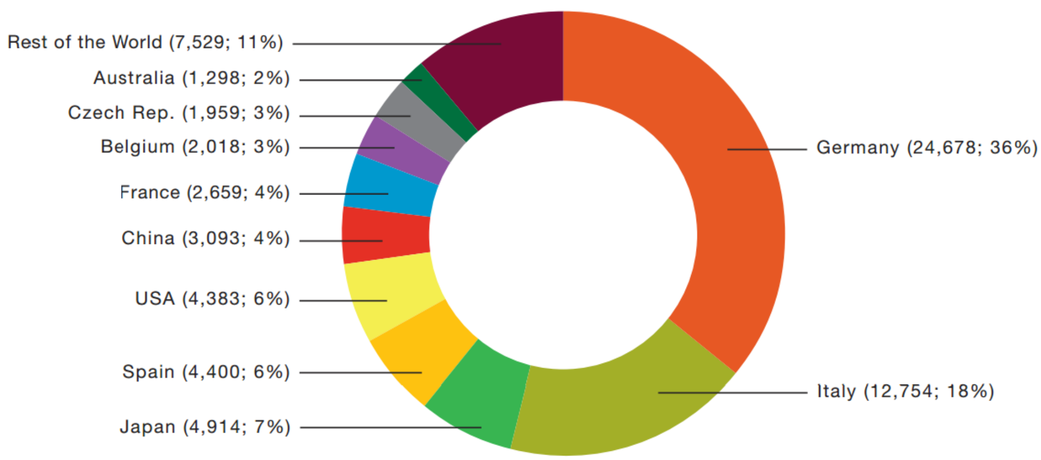


Figure 3: Global Cumulative Installed PV Capacity in 2011(MW) with market share (%).
An additional 27.4 GW of new PV capacity was installed in 2011 making the total global installed PV capacity 67.4 GW, 80 billion kWh or enough to power 20 million European households for one year. EPIA and NREL predict that total installed PV capacity will reach 100 GW by January 2013. The countries with the largest percent of grid-connected PV in 2011 were Germany, Italy, Japan, Spain and the US.
Source: European Photovoltaic Industry Association (2012)

As for the financing of the industry, in 2005 debt allocated to solar technologies totaled USD 146 million. By the end of 2010, debt extended to solar technologies had grown to USD 37.2 billion. "The role of debt (government-supported and non-government-supported) in the global solar industry continues to increase as banks and other lenders become involved in financing the operation and expansion of solar companies."[9] The expansion of credit, between 2004 and 2011, is a sign that the commercial credit market has reduced its perception of technology and market risk for solar. During the same time period, public equity offerings for solar companies grew from USD 1.7 billion to USD 7.9 billion. In 2009, Bloomberg, the financial news and data provider, completed an acquisition of New Energy Finance (NEF). NEF was started just years earlier to collect data on companies specializing in renewable energy as well as markets that were forming around carbon credits and carbon trading. Figure 4, from Bloomberg New Energy Finance, illustrates the global capital investment by security in solar energy from 2004 to 2011 in USD billions nominal.

[9] 2010 Solar Markets Trends Report: US Department of Energy (DOE)

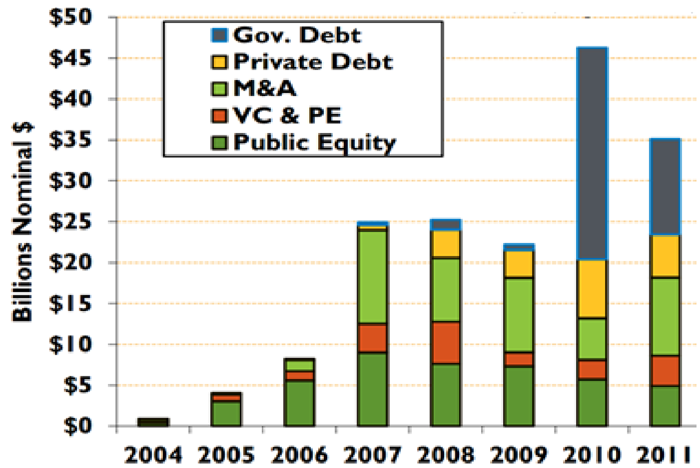


Figure 4: Global Capital Investment in Solar Energy 2004 – 2011 by Security in USD Billions Nominal.
The expansion of credit, between 2004 and 2011, is a sign that the commercial credit market has reduced its perception of technology and market risk for solar. Public equity offerings for solar companies grew from USD 1.7 billion to USD 7.9 billion, while debt offerings, both public and private, were over USD 15 billion for 2010 and 2011.
Source: Bloomberg New Energy Finance, New York, NY.

From an economic point of view, this is a positive sign for the global economy. In 2010, the China Development Bank issued over USD 23 billion in government-supported debt for solar projects. If more countries issue this type of government-backed debt in support of PVHS, they will be endorsing the development of a new technology (as compared to coal or nuclear), as well as fueling economic growth both domestically and globally. Alternatively, financing new coal or diesel plants and asking consumers to buy electricity from the grid advances "dated" technology, which does not contribute to economic growth. The Solow-Swan growth model[10] predicated that investment in new technology must be made in order for an economy to grow. Through investment in new technology, capital and labor would increase, leading to overall economic growth.

2.1.1 US Solar Energy Market

Currently, the US market for solar energy generation using PV has been advanced by incentives provided by municipal, state and federal governments. Given the current economic climate in the US and around the world, many of these incentives were discontinued in 2012 and will end in 2013, making the market much less attractive to investors, thus increasing the cost of small-, medium- and large-scale projects.

A number of factors make investors nervous, mainly the risk of cost recovery due to competing generation and transmission projects. On the other hand, earlier-than-expected power plant retirements may free up transmission capacity and provide further incentives for renewable resources. Transmission capacity requirements, low load hours, lack of flexible supply and demand resources, fledgling and imbalanced energy markets (such as those provided by PVHSs) work against solar developers procuring financing. Consequently, it is becoming more commonplace to see solar developers and independent power producers (IPP) partner with energy companies. Through partnerships the solar developers and IPPs gain access to the energy company's balance sheets and hence much needed financing. IPPs are private owners of electricity generating facilities who sell electricity to either utilities or end users.

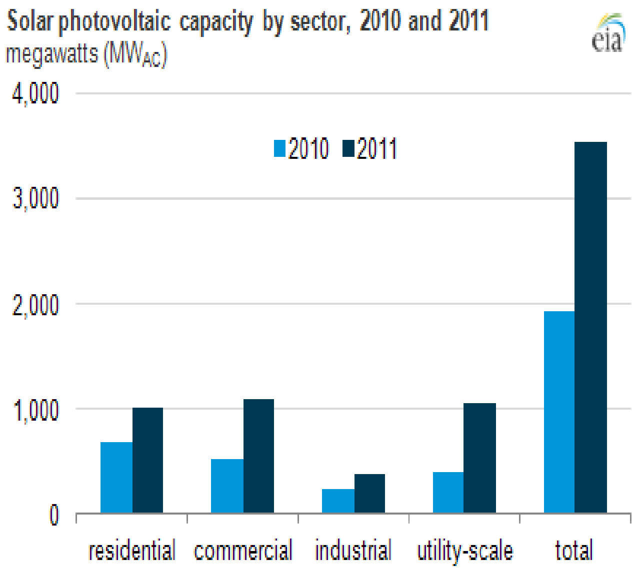
[10] Economic growth model published by Robert Solow in a 1956 paper, "A Contribution to the Theory of Economic Growth."

Solar power and offshore wind power are the most expensive ways to generate utility-sized electricity, according to the U.S. Energy Information Administration (EIA). This is not true of residential solar PV systems as they benefit from a number of variables, which utilities do not. For example, in a residential PV system, the homeowner already owns the land, while a utility would need to buy it. Additionally, home insurance also covers damages to the PV system. Municipal, state and federal regulations favor residential PV systems over utility-sized PV systems; there are more subsidies for residential PV owners provided by local utilities and government. Lastly, transmission and construction costs are much lower for residential PV systems, and no environmental studies are necessary for rooftop installation of residential PV systems. Although solar PV on a utility scale is considered restrictive due to high cost, the US Department of Energy (DOE) has provided loan guarantees, conditionally, for approximately USD 4.5 billion to support three enormous solar PV farms sponsored by First Solar (cumulative 1,330 MW). The DOE has offered conditional loans or loan guarantees to 40 clean energy projects totaling USD 38 billion, of which USD 16 billion is for utility-sized solar energy projects.

State renewable portfolio standard (RPS) requirements are time frames imposed by state governments necessitating an increase in renewable energy generation under penalty of fines for non-compliance. As a result, the utility sector invested four times more capital in solar technology in 2010 than in 2009. The RPS in some states has a specific quota that the utilities must comply with for solar energy generation so that each technology may be developed equally within the US. As a consequence of the expanded RPS requirements, a robust solar renewable energy certificate (SREC) market emerged providing further incentives to both investors and energy companies considering to trade or consuming these credits. SREC's are the utility sector solution to compliance with RPS without the need to build the costly PV infrastructure in state. Of the ten largest utility-sized PV installations, six were set up in 2010, according to the EIA.

The US market presents significant opportunities for aligning solar PV technology on a residential scale with financing sources, while benefiting from the regulatory challenges that have led to the creation of a new SREC market. The market is active as price movements in silicone, technologies and engineering to procure the best mix of PV system components is constantly in flux. The US solar market is highly fragmented with a plethora of incentives and impediments, which vary over the more than 3,000 utilities, over 100 municipalities, 50 states and the federal government. In Figure 5 we see the breakdown of PV capacity, in MW_{AC}, by residential, commercial, industrial and utility sector for 2010 and 2011. In 2010, residential installations were higher than utility-sized installations; in 2011 both residential and utility solar PV installed capacities were around 1,000 MW_{AC}. This signals that PVHS has room to grow given the same access to financing available to utility-scale developers.[11]

[11] EIA collects data on the electric power industry in alternating-current megawatts (MW_{AC}), while the PV industry in general discusses PV capacity in direct-current megawatts (MW_{DC}), because solar panels produce DC power.



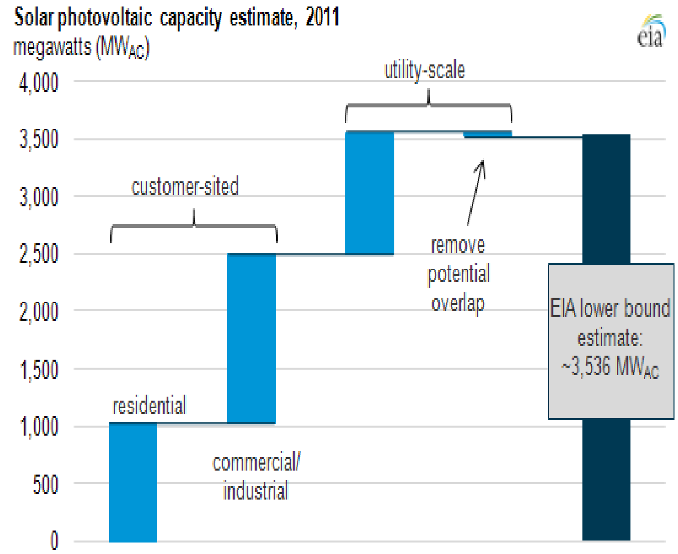


Figure 5: Solar PV Capacity by Sector 2010-2011 & Solar PV Capacity 2011 Estimate, Megawatts (MW_{AC}).
The capacity of residential solar PV installed in 2010, represented by the light blue bar on the far left, was greater than utility-scale solar PV installations. In 2011, the residential installation of new solar PV capacity was equal to utility-scale solar PV installations. Utility-scale growth was a reaction to the plethora of new financing afforded utility-scale projects in 2010-2011 through equity and debt.
Source: U.S. Energy Information Administration, Form EIA-861 Annual Electric Power Industry Report, and Form EIA-860, Annual Electric Generator Report.

Along the value-chain utility affiliates, IPPs and integrated PV manufacturers such as First Solar and SunPower are driving development and leading power purchase agreement (PPA) contract capacity nationwide. Analysts at other renewable energy data firms, such as GTM, estimate that in five years utility-scale solar projects will reach 3,000 MW annually, worth USD 8 billion. This scenario is highly dependent on DOE loan guarantees, manufacturer pricing and continued support of the industry through subsidies. On the other hand, PVHS installations have consistently risen over the past ten years regardless of manufacturer pricing or government subsidies. The world is not flat and the US solar market has been shaped by the complexities of fiscal, political, environmental and social policy. Innovative tools need to emerge to help smooth out the lumps in the market.

As of June 24, 2011, there were 391 early stage utility PV projects in the US; operating utility PV capacity was 419 MW and total contracted capacity was 8.6 GW, of which 1,045 MW had PPAs in place. Although there are over 3,000 utilities in the US, only 57 have actively pursued a large-scale PV PPA or project ownership. Of those utilities, only 18 have been involved in more than two projects. The utility market is currently signaling that it would like to own or produce solar PV generation so that it might meet regulatory demands in the SREC market. The majority of the utility solar PV that will be generated will not come on-line until 2015 if ever (as environmental and financial hurdles exist). Utility companies currently are buying SREC credits if they cannot produce the energy themselves. Figure 6 shows the ten largest US utility solar portfolios as of December 31, 2010, the ownership, size and technology of the systems. Six utilities have been meeting SREC demands through purchasing the solar PV energy directly from their customers.

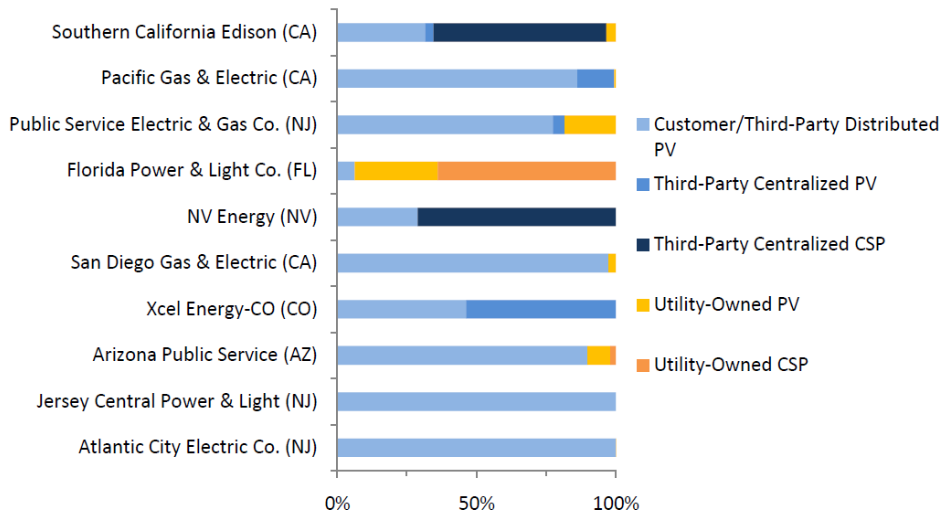


Figure 6: Top 10 US Utilities Solar Portfolio by Ownership, Technology and Size of Systems.
Of the top 10 utilities offering solar PV electricity in 2011 seven have greater than 75% of their solar portfolio coming from customer or third-party distributed PV systems. Two are using a majority of third part owned centralized concentrating solar power (CSP) as well as customer or third-party distributed PV systems. Only one utility in 2011 had PV and CSP generation systems that were utility-owned.
Source: Solar Electric Power Association: Report #01-11

2.1.2 Cost Effectiveness and LCOE of PVHS

Solar energy is abundant, inexhaustible and clean. The power from sun intercepted by the earth is about 1.8×10^{11} MW, which is many times larger than the present rate of all energy consumption.[12] The quantity of electricity generated from a solar PV system depends on its geographical location due to the technology's sensitivity to solar irradiation and ambient temperature. Cost effectiveness, for the purposes of this work, means that the PVHS achieves energy generation at the lowest cost while continuing to provide incentives to lenders. I will examine decentralized PVHS cost effectiveness through the lens of a commercial credit institution. We know that utility-sized solar and wind projects are the most expensive and hence the least cost effective according to the EIA. The alternative to PVHS is grid-connected, utility-sized coal, gas or other fossil-fuel-burning technology. In order for PV technology to work most efficiently, it requires high solar radiation and low temperature. This makes it difficult to obtain a static figure that accounts for the energy generated from any given PVHS as compared to alternatives. However, consumption of electricity is also dynamic. We know that PV systems function during two of the three peak periods of the day: morning and mid-day.

I will use what is considered to be the standard in both professional and academic circles to calculate the cost effectiveness of new versus vintage technologies for power generation, levelized cost of energy (LCOE). "The economic feasibility of an energy generation project can be evaluated using various metrics, but the levelized cost of electricity generation is most often used when comparing electricity generation technologies or considering grid parity for emerging technologies such as PV".[13] The LCOE method assesses the cost effectiveness of different energy generation technologies in a dynamic manner.[14] It provides a snapshot of the cost effectiveness of the technology by considering the lifetime generated energy and costs, in price per unit of energy generated. This paper endeavors to contribute an alternative view to existing business models and financing alternatives which

[12] Bhubaneswari, Iniyan and Ranko
[13] Brankera, Pathaka and Pearce
[14] Brankera, Pathaka and Pearce

could be considered in LCOE, a standardized tool for calculation. In other words, LCOE allocates the costs of an energy plant across its useful life and averages the up-front costs across production over a long period of time. The underlying assumptions based in the calculation of LCOE are as follows.

Nomenclature	
T	Life of the project [years]
t	Year t
C_t	Net cost of project for t [$]
E_t	Energy produced for t [$]
I_t	Initial investment/cost of the system including construction, installation, etc. [$]
M_t	Maintenance costs for t [$]
O_t	Operation costs for t [$]
F_t	Interest expenditures for t [$]
r	Discount rate for t [%]
S_t	Yearly rated energy output for t [kWh/year]
d	Degradation rate [%]

"*The sum of the present value of LCOE multiplied by the energy generated should be equal to the present valued net costs. The summation calculation starts from t = 0 to include the project cost at the beginning of the first year that is not discounted and there is no system energy output to be degraded.*"[15]

$$\sum_{t=0}^{T}\left(\frac{\mathrm{LCOE}}{(1+r)^t}\times E_t\right)=\sum_{t=0}^{T}\frac{C_t}{(1+r)^t}$$

Net cost of the project or C_t, is the sum of the net present value of the initial investment, total operation costs, total maintenance costs and financing costs. In other words, the sum of capital expenditure and the net present value of total operation and maintenance costs divided by the net present value of total energy production. The source of financing of the PVHS is critical; the LCOE will change depending on what financial instrument is used.

$$\mathrm{LCOE}=\frac{\sum_{t=0}^{T}(I_t+O_t+M_t+F_t)/(1+r)^t}{\sum_{t=0}^{T}E_t/(1+r)^t}=\frac{\sum_{t=0}^{T}(I_t+O_t+M_t+F_t)/(1+r)^t}{\sum_{t=0}^{T}S_t(1-d)^t/(1+r)^t}$$

"*Finally, the net costs will include cash outflows like the initial investment (via equity or debt financing), interest payments if debt financed, operation and maintenance costs (note: there are no fuel costs for solar PV) and cash inflow such as government incentives. As such, the net cost term can be modified for financing, taxation and incentives as an extension of the initial definition.*"[16]

[15] Brankera, Pathaka and Pearce
[16] Brankera, Pathaka and Pearce

$$\mathrm{LCOE} = \frac{\sum_{t=0}^{T} C_t/(1+r)^t}{\sum_{t=0}^{T} E_t/(1+r)^t}$$

"The energy generated in a given year (E_t) is the rated energy output per year (S_t) multiplied by the degradation factor ($1 - d$) which decreases the energy (electricity production) with time. The rated energy output per year can be determined by multiplying the system size/capacity in kW by the local solar insolation that takes capacity factor into account in the units: kWh/kW/year$_1$. Traditionally, this value is determined by multiplying the number of days in the year by average number of hours per year the solar PV system operates by system size to get the final units of kWh/year."[17]

A number of researchers believe that LCOE figures for solar PV can be elevated due to distortions or externalities that are not properly accounted for in the variables.[18] Notwithstanding in April 2011 the California Public Utilities Commission published a report whereby they found PVHS to be cost effective in San Diego, California.[19] Using the same formula described above the commission obtained results in 2009 that estimated a PVHS would cost USD 0.523/ kWh. Given a CSI Rebate of USD 0.083/kWh, avoided bills of USD 0.356/kWh, REC revenue of USD 0.022/kWh, State taxes of USD 0.012/kWh and Federal taxes of USD 0.135/kWh the benefit of this system would be of USD 0.608/kWh making the PVHS cost effective according to this commission (Figure 7).

Residential PV (Levelized $/kWh)

	2008	2009
System Cost	-0.555	-0.523
CSI Rebate	0.107	0.083
Avoided Bills	0.342	0.356
REC Revenue	0.02	0.022
State Taxes	0.011	0.012
Federal Taxes	0.134	0.135
Net Benefits	**0.059**	**0.086**

**Source: California Public Utilities Commission, April 2011*

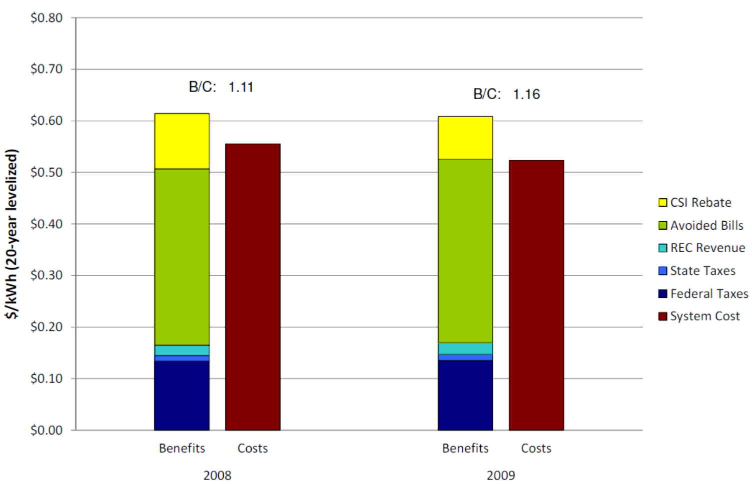


Figure 7: LCOE for Average PVHS in San Diego, California 2008-2009.
The California Public Utilities Commission concluded that the cost of a PVHS (red bar on the right) was less than the benefit afforded through tax savings, REC revenue, avoided bills and CSI rebate (blue, green and yellow bar) for California residents. The conclusion was that the benefit afforded to California residents who invested in a PVHS was USD 0.059 per kWh in 2008 and grew to USD 0.086 per kWh in 2009.
Source: California Public Utilities Commission April 2011

This cost effectiveness study was done compared to peak power natural gas plants in California. The EIA has calculated the LCOE for various centralized utility sized technologies, as noted in Figure 8, range from USD 0.058/kWh to 0.400/kWh. Solar PV on a utility sized scale has a LCOE of between USD 0.122/kWh to 0.245/kWh which makes it one of the most expensive and hence least cost effective centralized energy production methods. The various studies citied in Appendix 1 found LCOE ranges of a variety of

[17] Brankera, Pathaka and Pearce
[18] Brankera, Pathaka and Pearce
[19] California Solar Initiative Cost-Effectiveness Evaluation

solar PV technologies and applications, according to numerous authors on the subject, in North America from USD 0.15 to 0.80/kWh for PVHSs.

Plant Type	Range for Total System Levelized Costs (2010 USD/MWh)		
	Minimum	Average	Maximum
Conventional Coal	90.1	99.6	116.3
Advanced Coal	103.9	112.2	126.1
Advanced Coal with CCS	129.6	140.7	162.4
Natural Gas Fired			
Conventional Combined Cycle	61.8	68.6	88.1
Advanced Combined Cycle	58.9	65.5	83.3
Advanced CC with CCS	82.8	92.8	110.9
Conventional Combustion Turbine	94.6	132.0	164.1
Advanced Combustion Turbine	80.4	105.3	133.0
Advanced Nuclear	108.4	112.7	120.1
Geothermal	85.0	99.6	113.9
Biomass	101.5	120.2	142.8
Wind	78.2	96.8	114.1
Wind — Offshore	307.3	330.6	350.4
Solar PV	122.2	156.9	245.6
Solar Thermal	182.7	251.0	400.7

Figure 8: Regional Variation in Levelized Costs of New Utility Sized Generation Resources.
Solar PV on a utility sized scale has a LCOE of between USD 0.122/kWh to 0.245/kWh which makes it one of the most expensive and hence least cost effective centralized energy production methods. As a PVHS is a residential sized, decentralized energy production method the costs and benefits differ making PV solar cost effective for decentralized energy production but not for centralized energy production.
Source: Energy Information Administration, Annual Energy Outlook 2012. June 2012, DOE/EIA-0383

As PVHS produces decentralized electricity, it would be inaccurate to compare the LCOE of a PVHS to that of a centralized energy generator. A PVHS is not subject to the same transmission, operation and maintenance costs as is a utility scale power plant. Finally, the fuel used to power a PVHS is the sun whereas coal, diesel or natural gas power plants need to consume fossil fuels to generate power. For these reasons I will consider the cost effectiveness for a PVHS as compared to the cost of electricity that would be provided by the grid to a residential home in Lisbon, Portugal or San Diego, California. The range of prices that exist in the market for electricity in the US are from 0.06 – 0.30 USD/kWh according to the EIA. In Figure 9 we see the average price per kWh as of September 2012 in the US was USD 0.124/kWh up from USD 0.114 in January of this year.

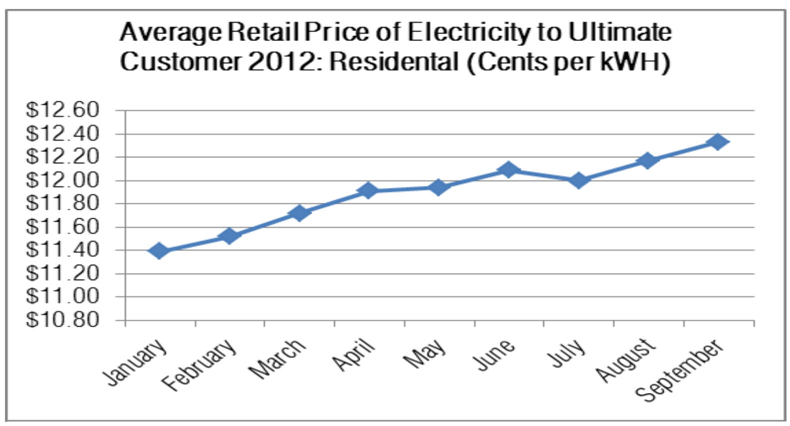


Figure 9: Average Retail Price of Electricity to Ultimate Customer 2012: Residential ₵/kWh.
In 2003 the average price of electricity to the average residential consumer in the US was 8.73 ₵/kWh. In September 2012 the price has jumped to 12.40 ₵/kWh, a growth of 42% in the past nine years.
Source: US Energy Information Administration (2012)

At this point I would like to reiterate that the focus of this paper is a specific PVHS, described in Appendix 9 and 10, that will be installed in Lisbon, Portugal or San Diego, California USA. If either the PVHS components or location change the following data would no longer apply. Given a *Life of the Project* (T) of 30 years; *Net Cost of the Project* (C_t) of USD 20,240; *Energy Produced for time t* (E_t) of USD 725.40 (*Vazio* Rate), USD 1,236.70 (*Cheio* Rate), USD 1,458.35 (*Ponta* Rate); *Initial Investment* (I_t) of USD 20,240; *Maintenance Costs for time t* (M_t) of USD 80; *Operation Costs of time t* (O_t) of USD 80; *Interest Expenditures for time t* (F_t) of USD 1,206.27; *Discount Rate* (r) of 3.5%; *Yearly Rated Energy Output for time t* (S_t) of 5,997 kWh/year; and a *Degradation Rate* (d) of 0.80% using the LCOE formula described above, I calculated the LCOE Nominal to be 23.70 ¢/kWh and a LCOE Real to be 17.81 ¢/kWh. On the initial investment of USD 20,240 the after-tax NPV, of the cash flow produced by the PVHS, is USD 10,230.21 and the payback period is 11.3217 years. The calculations can be found in Microsoft Excel workbook format in Appendix 7.

The after-tax NPV is the difference between the sums of discounted cash inflows from after tax cash flows and cash outflows from debt total payment (Appendix 7). As I do not know what the price of electricity sold on the grid will be in the future or what individual consumption might be, I decided to calculate NPV based on information that was available and reliable. I would like to note, I used a static inflation rate of 2.5% for all calculations. The nominal discount rate I calculated for this PVHS is 6.09% (Nominal discount rate = [1 + Real Discount Rate] x [1 + Inflation Rate] -1). For these projects, the discount rate represents the value of an alternative investment of I_t.

If a residential consumer were to buy electricity from the grid, specifically EDP, the price would vary, depending on the time of day, between 0.0864 (*vazio*) – 0.1473 (*cheio*) – 0.1737 (*ponta*) Euros per kWh.[20] At an exchange rate of 1.40 USD per EUR (exchange rate that Goldman Sachs Group predicts for 2013 in their October 3, 2012 Report: *Economics, Commodities and Strategy Research: Top of Mind*) that would translate to 0.1209 (*vazio*) – 0.2062 (*cheio*) – 0.2431 (*ponta*) USD per kWh. Although the LCOE Nominal of the PVHS in Lisbon, Portugal is below the *ponta* rate it is above the *vazio* and *cheio* rates. The LCOE Real is below both the *cheio* and *ponta* rates but above the *vazio* rate. Figure 10 shows us the variables used to calculate the PVHS LCOE.

VAZIO		
T	30	*Years*
Ct	20,240	*USD*
Et	725.40	*USD*
It	20,240	*USD*
Mt	80	*USD*
Ot	80	*USD*
Ft	1,206.27	*USD*
r	3.5	*%*
St	5997	*kWh/year*
d	0.8	*%*

CHEIO		
T	30	*Years*
Ct	20,240	*USD*
Et	1,236.70	USD
It	20,240	*USD*
Mt	80	*USD*
Ot	80	*USD*
Ft	1,206.27	*USD*
r	3.5	*%*
St	5997	*kWh/year*
D	0.8	*%*

PONTA		
T	30	*Years*
Ct	20,240	*USD*
Et	1,458.35	USD
It	20,240	*USD*
Mt	80	*USD*
Ot	80	*USD*
Ft	1,206.27	*USD*
r	3.5	*%*
St	5997	*kWh/year*
D	0.8	*%*

Figure 10: LCOE Variables for *Vazio*, *Cheio* and *Ponta* EDP Prices Using SAM Computer Modeling Software.
E_t or the price at which energy is produced changes in the three scenarios (*vazio, cheio, ponta*) presented so that the reader might compare the cost of centralized electricity and PVHS at the current EDP rates for Lisbon, Portugal. E_t is therefore S_t multiplied by the EDP rate *vazio, cheio,* and *ponta* respectively. S_t (electricity output of PVHS) is calculated by multiplying yearly output and one minus a degradation rate divided by one plus the discount rate. In other words the NPV of total energy production will act as the denominator. We do this because it is unclear what the EDP rates will be in 5, 10 or 30 years.
Source: David N Pereira

[20] Residential rates quoted on EDP website (http://www.edpsu.pt/pt/particulares/tarifasehorarios/BTN/Pages/TarifasBTNate20.7kVA.aspx)

Although the rates for electricity at *vazio*, *cheio* and *ponta* rates occur at different times of the day by using S_t (yearly rated energy output) we can more easily calculate LCOE. The LCOE was calculated using a computer model developed by the DOE and NREL called the System Advisory Model (SAM) and Microsoft Excel (Appendix 7 shows the Excel workbook for the Lisbon PVHS).[21] Both the LCOE Real and Nominal is lower than the benefit offered by the main utility supplier, EDP, which is USD 0.287/kWh (rate at which EDP will enter into a ten year PPA with residents who own a PVHS in 2013). Therefore the rates at which the consumer can purchase grid connected electricity is lower than the rate that EDP will pay a resident to produce their own electricity. In Figure 11 I take this parameter into account and consider a scenario where the owner of the PVHS in Portugal was to sell 100% of their production back onto the grid. Using the same parameters and variables described above, except E_t, we can see that E_t is greater than F_t thereby making the PVHS cost-effective with a profit of USD 514.87 in year one. Grid parity does not exist during *vazio* pricing for the Real LCOE of the PVHS. If the interest rate on the financing were to rise by as little as 1%, in nominal terms, grid parity would not exist in any of the three scenarios. However, given the current price incentive offered by EDP it is cost-effective to own a PVHS until the point where the homeowner's monthly interest payments equal USD 1,721.14.

Current Offer EDP (0.287 cents/kWh)		
T	30	*Years*
Ct	20,240	*USD*
Et	1,721.14	*USD*
It	20,240	*USD*
Mt	80	*USD*
Ot	80	*USD*
Ft	1,206.27	*USD*
r	3.5	*%*
St	5997	*kWh/year*
D	0.8	*%*

Figure 11: LCOE Variables for EDP Contracted PVHS Using SAM Computer Modeling Software.
If the PVHS in Lisbon, Portugal was to sell 100% of their production back onto the grid at the EDP PPA pricing E_t is greater than F_t (interest and principal expenditures for PVHS) thereby making the PVHS cost-effective with a profit of USD 514.87 in year one. Grid parity does not exist during vazio pricing for the Real LCOE of the PVHS.
Source: David N. Pereira

The financing parameters for the above LCOE calculations were 100% debt over 30 years with an interest rate of 4.25% per year and a principal amount of USD 20,240.00. I did not include VAT or taxes for the purchase of the PVHS (as regulations vary for US and EU). Finally, I assumed the owner of PVHS would consume 100% of the energy produced in Figure 10 and would sell 100% of production in Figure 11.

Given the same parameters above, if the PVHS were to operate in San Diego, California then the LCOE variables would change slightly as seen in Figure 12.

[21] SAM makes performance predictions and cost of energy estimates for power projects based on installation and operating costs and system design parameters that you specify as inputs to the model. (https://sam.nrel.gov/)

San Diego, California		
T	30	*years*
Ct	20,240	*USD*
Et	1,086.83	*USD*
It	20,240	*USD*
Mt	80	*USD*
Ot	80	*USD*
Ft	1,206.27	*USD*
R	3.5	*%*
St	6627	*kWh/year*
D	0.8	*%*

Figure 12: LCOE Variables for PVHS in San Diego, California Using SAM Computer Modeling Software.
The price of centralized, grid consumed electricity charged by San Diego Gas and Electric varies between USD 0.164 and 0.254 per kWh. The Et above is calculated using the lower estimate of USD 0.164 however at the highest rate E_t would equal USD 1,683.25. The Nominal LCOE is 21.45 ¢/kWh and the Real LCOE is 16.12 ¢/kWh making the PVHS cost effective only at the USD 0.254 per kWh rate. However, since CSI pays PVHS owners between USD 0.22 - 0.39 for the first 130MW produced the PVHS is cost-effective.
Source: David N. Pereira

As the solar radiation and temperature in San Diego, California are different than in Lisbon, Portugal we see an increase in S_t. Also, as noted in Figure 9, the average price per kWh in the US is 12.40 cents per kWh however in San Diego, California the rates for electricity vary by season (winter versus summer) and peak times (on-peak vs. semi-peak vs. off-peak). The rate charged by San Diego Gas and Electric varies between USD 0.164 and 0.254 per kWh.[22] At the lowest rate E_t would equal USD 1,086.83 however at the highest rate E_t would equal USD 1,683.25. The Nominal LCOE is 21.45 ¢/kWh and the Real LCOE is 16.12 ¢/kWh. The PVHS is only cost effective at summer peak times when the rate is USD 0.254 per kWh at all other rates the PVHS is not cost effective. However, Appendix 4 highlights the benefits afforded to PVHS owners through the California Solar Initiative (CSI); the CSI pays owners of PVHS between USD 0.39 and 0.22 cents per kWh for the first five steps or 130MW[23] of electricity produced. The specific PVHS we are studying would produce 130MW in the first 19 years of operation making the PVHS cost effective and profitable.

The I_t used was calculated by the SAM computer software. SAM predicted for the PVHS described in Appendices 9 &10 a cost of 3.91€/Watt *ponta* ($5.09/Wp). When I asked Efacec Renewables in Maia, Portugal to produce an estimate of the same exact PVHS as used by SAM, they confirmed that to install the same PVHS the cost would be around 2€/Watt *ponta* ($2.59/Wp). I used the higher estimated cost although PVHS component prices are falling so that the LCOE calculation might be more robust. Had I used the estimate provided by Efacec Renewables the LCOE Nominal would be 19.39 ¢/kWh and a LCOE Real would be 14.57 ¢/kWh, all other variables being the same as Figure 11.

The large capital cost and the cost of financing is what is being scrutinized in this paper. Miniscule shifts in either capital cost or cost of financing can make or break the cost effectiveness of the PVHS being studied. If we deconstruct the capital costs in a manner that reflects the dynamics of the market, we note that the case for grid parity does exist.

I used, what would be considered in the commercial credit market, a low or social discount rate. Without using this lower discount rate grid parity would not be possible as the financing costs of the PVHS would create a higher LCOE. The perceived risks of an

[22] San Diego Gas and Electric website; Overview NEM Rates (http://www.sdge.com/clean-energy/overview/overview-nem-rates)
[23] California Solar Initiative: San Diego, Residential Solar PV Rebates (2012)

asset as well as the time value of money are variables that commercial lenders take into account when determining which discount rate should be used. In the UK *The Green Book: Appraisal and Evaluation in Central Government Treasury Guidance* stipulates a discount rate of 3.5% should be attributed to PVHSs. Similarly, in Canada, the rate that is suggested for individuals investing in PVHSs is between 3.5%-4.5%. The reason for such a low rate is because these governments have revalued the discount rate for PV technology using what is called a Social Time Preference Rate, or rather the standard real discount rate. Society has attached a lower marginal utility and a higher future cost to overconsumption of fossil fuel burning technologies in the present. In financial theory cash outflows are preferred in the far term while cash inflows are desired in the near term. Given current discount rates it is believed that consumptive or fossil fuel burning technologies meet these criteria better than capital intensive or renewable technologies. PVHSs have shorter installation times, higher upfront costs and no fuel costs. On the other hand consumptive technologies have longer installation times and higher fuel costs. It should be that renewable technologies receive a lower discount rate however this is not the case probably due to the perceived risk of using a newer technology. [24]

The assumptions have an important effect on the PVHSs LCOE compared with larger utility sized projects. "Grid parity could occur today under certain financial circumstances with the new method."[25] The new method that is described by Branker, Pathak and Pearce is one where LCOE is calculated using a longer working life of the PVHS; a variable for the rise in electricity prices over time is added (to capture the effect in Figure 9); and degradation rates of the PVHSs are lowered based on scientific research. These are all reasonable assumptions given current data. The working life of an asset, for a commercial credit provider, is the time that the asset continues to produce cash flow. In the case of a PVHS the working life is normally calculated as the time the components are under warranty by the manufacturer. This is incorrect as studies have found that most PVHS continue to work with more than 80% of efficiency past their warranty periods. "A 30 year term is … likely to become the new industry standard for solar PV warranties."[26] Ofgem, the UK's energy and gas market regulator, has told consumers to expect the price of energy to rise 20% between now and 2020.[27] Finally, studies have found that more than 70% of PVHSs, which have between 19 and 23 years of operation, have an annual degradation rate of 0.75% which is less than the 1.0% which is assumed for most financial models.[28] It is therefore safe to assume, for the purposes of this paper, that a PVHS manufactured today will have a longer life; and a lower degradation rate than a system manufactured 23 years ago.

Concerning grid parity or cost-effectiveness of PVHS we have not considered the indirect and direct subsidies that are afforded to consumptive technologies such as nuclear, coal and diesel power generation plants. In a study conducted by the Environmental Law Institute in the US, they found that between 2002 and 2008 subsidies to fossil fuels totaled approximately $72 billion whereas subsidies to renewable fuels were $29 billion (Appendix 3). As subsidies vary between Portugal and the US we will not consider subsidies in the calculation of LCOE for this study. Further, it is worthwhile to comment that currently coal fired power plants are considered to be able to produce energy for the grid at the lowest cost, roughly an LCOE of between 0.08 and 0.10 cents per kWh, according to the EIA. Recently, studies have been done on the real cost of coal for the production of electricity that find that "the best estimate for the total economically quantifiable costs, based on a conservative weighting … amount to some $345.3 billion,

[24] Brankera, Pathaka and Pearce
[25] Brankera, Pathaka and Pearce
[26] BBC News
[27] The Guardian
[28] Brankera, Pathaka and Pearce

adding (to the estimate of 0.08-0.10 cents per kWh) close to 17.8¢/kWh of electricity generated from coal. The low estimate is $175 billion, or over 9¢/kWh, while the true monetizable costs could be as much as the upper bound of $523.3 billion, adding close to 26.89¢/kWh . . . Accounting for the many external costs over the life cycle for coal-derived electricity conservatively doubles to triples the price of coal per kWh of electricity generated." [29]

Governments outside the US and Portugal have already begun to realize that PVHS are good investments. In the case of the United Kingdom the government promises to pay each PVHS investor £1,000.00 per year for 25 years, so as to help citizens cover the loan's principal and interest. This type of government assistance could be seen by commercial lenders as a loan guarantee, thereby lowering risk that the borrower will not repay the loan. The average cost of a 2.5kW PVHS is between £10,000 - £12,500 and consumers will initially be paid 41.3 pence per kWh generated, benefiting them an average of £900 in the first year and saving them £140 per year (at current electricity prices) on their bills for the next 30 – 40 years.[30] These government incentives create the case whereby PVHS becomes cost effective in the UK regardless of weather and geography. A similar subsidy was provided in Germany, Japan and Australia decreasing the risk to lenders significantly and even profiting PVHS consumers in the long run.

The technologies that comprise the PVHSs are ever changing, becoming more efficient in terms of energy generation and of superior quality in terms of production process learning. What is important to note is that the efficiency of the technology that currently exists is cost effective, hence economically feasible, for individual consumption more so than for utility application. Through industrial symbiosis and technological experience the cost of the components of the PVHS are decreasing as well as the cost of installation (see Appendix 2). The cost-effectiveness of the PVHS today, during peak hours, has been proven. As quality improves and costs fall, in the future, we know that the PVHS will be more competitive.

2.1.3 Incentives and Hindrances to Solar PV Adoption

In the US there exist various incentives in the form of PPAs, rebates, tax credits and so on for the adoption of solar PV technology. For example, the residential energy conservation subsidy exclusion is a personal Federal tax exemption on PVHS. Internal Revenue Service (IRS) Form 5695 details that residents may benefit from a 30% federal tax exemption on the cost of labor and connection to the home, of a PVHS, that may be carried forward, if need be, until 2016. This exemption may be applied to solar-electric systems, solar water heating systems and fuel cells in accordance with the Energy Policy Act of 2005. However, the IRS has not yet ruled definitively on IRS Publication 525, which allows that PVHSs and utility subsidies be considered non-taxable items. On the issue of residential energy credits (otherwise known as carbon credits), the residential energy conservation subsidy exclusion protects investors from paying taxes on any income earned from the sale of these credits.

The federal tax exemption on labor and connection costs is in effect until December 31, 2016 but faces political risk as to if it will be renewed again before its expiration. It appears, however, that politicians on both sides have been voting in favor of solar PV investment. Through the creation of the Energy Policy Act of 2005 the Republican Party favored solar PV; in 2009, under a Democratic Party rule, the cap on capital investment was removed and the tax benefits extended eight years.

[29] Epstein et al.: "In quantifying the damages, we have omitted the impacts of toxic chemicals and heavy metals on ecological systems … the direct risks and hazards posed by sludge, slurry … the full contributions of nitrogen deposition to eutrophication of fresh and coastal sea water; the prolonged impacts of acid rain and acid mine drainage… some of the health impacts and climate forcing due to increased tropospheric ozone formation; and the full assessment of impacts due to an increasingly unstable climate. The true ecological and health costs of coal are thus far greater than the numbers suggest."
[30] The Guardian

In addition to the two personal tax credits offered by the federal government for PVHS, 24 states offer similar credits on state tax, 30 states offer exemptions on sales tax, 40 states have exemptions for property taxes and 47 states have utilities that offer rebates for PVHSs. These incentives, credits, exemptions and rebates vary from state to state but are quickly becoming commonplace. For example, Arizona Electric District No. 3 of Pinal County is a utility that provides a USD 0.20 per watt rebate (on the cost of the PVHS) for their residential customers to invest in PVHSs of up to 10 kW. Commercial customers can install PV systems up to 20 kW but the rebate cannot be greater than 50% of the installed cost. Tucson Electric Power (TEP) created the SunShare Program in 2001 whereby the utilities must pay PVHS owners for their RECs as mandated by the State of Arizona. PVHS restrictions apply so that PVHS with less than a 20 year warranty on the module (solar panel) or a 10 year warranty on the inverter do not qualify.

Incentives also come in the form of community awareness or rather public information. The DOE SunShot Initiative is working towards reducing the costs of installation for solar PV by 75 percent and spurring large-scale adoption of solar PV so as to restore US leadership in the global clean energy race. The Connecticut Clean Energy Finance and Investment Authority (CEFIA) were created this year so as to develop solar incentives that will result in a minimum of 30 MW of new residential solar PV by December 31, 2022.

In terms of low interest loans, there is only one offered in the United States, for PVHS in Arizona. Sulphur Springs Valley Electric Cooperative (SSVEC) offers customers a 3% loan (up to USD 2.00 per watt) for 25 percent of the total cost of a 1 to 4 kW PVHS. The loan program has limited funds and is managed on a first come, first served basis.

The Federal Energy Regulatory Commission (FERC) was created to accelerate and enable the long distance transmission of electricity (from a centralized power generator). FERC has access to cheap financing and currently offers a higher return on investment in high voltage transmission lines rather than power plants or lower voltage lines. "States have actively expressed their opposition to being forced to pay for a new transmission infrastructure that assumes they will be importers rather than generators of renewable energy." [31] FERC is against solar PV technology and argues that PVHS are expensive and inefficient. It is important to note that the techniques used to calculate the cost-effectiveness of PVHS are not the most appropriate as regulatory costs shift in favor of renewable energy.

Also working against PVHS are the loan guarantees provided by the DOE to support large-scale, centralized, solar PV projects. The loan guarantee lowers the risk to the creditor by implicating that the federal government will pay the loan back if the developer is unable to meet their obligations. Finally, the solar permitting costs in the US average USD 2,500 per project and can raise project costs by as much as 10 to 20 percent.

2.2 Current Business Models for PVHS

The market for PVHSs has been constantly changing over the past forty years. In the US this change has been driven primarily by regulations created by state governments and policies enacted by utility companies. Recently, non-governmental organizations as well as the federal government have had a hand in shaping public perceptions and incentives to enter the market. As the dynamics

[31] Varela, Robert

of the market affect the potential business models for PVHS, it is important to understand the incentives, hindrances, risks and rewards offered to the players. The constant "update" of information and policy has led to some business models, for solar PV, to become outdated. We know that policy and financial incentives in Germany and Japan have led to the adoption of solar PV in both utility and residential sized projects, catapulting these countries to the frontier of solar PV electricity generation, a position highly desired by the US.

Some of the players who are currently active in the market are component manufacturers, individuals, laboratories, universities, town and city councils, policymakers, utilities, communities, solar developers, solar brokers, IPPs, solar PV installers, solar PV operators, solar PV maintenance companies, regulators, commercial, retail and investment banks. I will elaborate on the players as I explain the different business models which currently exist as well as the ones I would like to create.

NREL, for example, is the only federal laboratory dedicated to the research, development, commercialization and deployment of renewable energy and energy efficiency technologies.[32] On the other hand there are hundreds of solar developers and installers in the United States who can source their components from a handful of component manufacturers. However, if the solar installer needs help sourcing clients there is only one solar broker.

Please find a matrix on the last page which summarizes the current business models for PVHS that will be discussed below.

2.2.1 Energy mortgages - Decentralized

Energy mortgages constitute a US federal loan program which offers financing to improve a current home or assist in the purchase of a new home by qualified taxpayers. This federal loan program is only available for passive solar space heat (using local climate and building design to regulate hot and cold air), solar water heat, solar space heat (can be active, using solar PV technology, or passive), PVHS and daylighting (similar to passive solar but focused on taking advantage of natural light for internal lighting purposes). "An energy mortgage is a mortgage that credits a home's energy efficiency in the home loan. For an energy efficient home, for example, it could mean giving the home buyer the ability to buy a higher quality home because of the lower monthly costs of heating and cooling the home. For homes in which the energy efficiency can be improved, this concept allows the money saved in monthly utility bills to finance energy improvements."[33] There are two types of energy mortgages. The first is an energy improvement mortgage which is afforded to individuals who are considering to upgrade their existing home with energy saving upgrades such as better insulation, new windows and efficient heating and cooling systems. The second is energy efficient mortgages which uses the energy savings from a new energy efficient home to increase the home buying power of consumers and capitalizes the energy savings in the appraisal.

These financing options are limited to USD 4,000 or 5% of the appraised value (whichever is greater) up to a maximum of USD 8,000 which means homeowners can spend up to 5% of the appraised value of the home on energy improvements and thereby qualify for a loan that is 5% greater than they would have received under normal underwriting conditions. Lenders also guarantee that the appraised value of the home will increase by the amount the borrower spends on improvements. For instance, if a homeowner plans to increase his mortgage by USD 8,000 for a PVHS, that would add roughly USD 48.00 per month to his loan

[32] NREL
[33] RESNET

payment (assuming a 30-year fixed mortgage at 6%). On the other hand the cap on the loan of USD 8,000 means that it wouldn't cover the full cost of the PVHS. Moreover, the PVHS would have to be approved by an auditor and the loan is only available through mortgage programs insured by the US Federal government. Insured programs belong to government sponsored enterprises such as Freddie and Fannie who help expand the secondary mortgage market so that capital and lenders can grow and bring down interest rates.

2.2.2 Power Purchase Agreements (PPA) - Decentralized

PPAs can be structured in a variety of ways. In a third party ownership model the homeowner hosts a PVHS on their property and a solar developer purchases, installs, owns, operates, and maintains the system (Figure 13 shows, in flow diagram form, how a residential Solar PV PPA agreement works). The homeowner does not purchase or own the PVHS but instead enters into a PPA, with the solar developer, to buy the electricity produced (electricity is not intended for sale on the grid but if the homeowner is not consuming electricity it can be sold to a third party). The PPA is typically priced at or below the prevailing utility retail rate in the first year with some fixed rate escalation over the life of the agreement. In this model the homeowner does not own the PVHS or

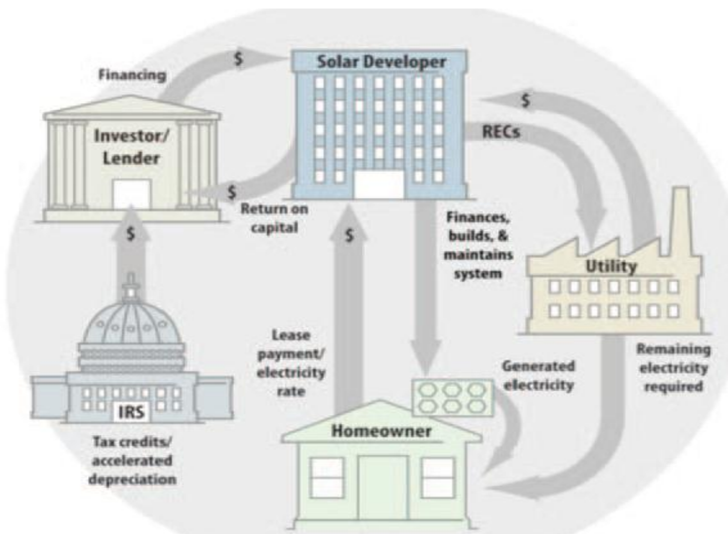


Figure 13: Flow Chart of a Solar Residential PPA Model.
In the Solar Developer PPA model a Homeowner enters into a PPA with a Solar Developer. The Solar Developer then enters into a PPA with the Utility and receives financing from an Investor/Lender. The Solar Developer, Utility and Investor/Lender then share the benefits (IRS and REC) afforded the PVHS owner.
Source: US DOE and NREL; 2010 Solar Technologies Market Report

have to incur the large up front capital cost of the PVHS. Utilities in turn sign PPAs with solar developers so that the solar developer can obtain lower cost financing. The lower rate offered by utilities to the solar developer allows the developer to profit from the difference in what is charged by the utility and to consumer. The solar developer receives the monthly cash flows in the form of power sales to the homeowner, the fully monetized federal tax benefits (only in the US) which include an investment tax credit (ITC)[34] and accelerated depreciation of the asset. In addition, electricity and RECs are produced simultaneously therefore the owner of the PVHS is the owner of the REC. In the case presented in Figure 13 the solar developer is the owner of the PVHS therefore owns the REC and sells it to the utility. Usually, PPAs cover a 15 to 20 year period starting when the PVHS becomes operational,

[34] The ITC is a 30 percent tax credit for solar systems on residential (under IRS Section 25D) and commercial (under IRS Section 48) properties. Under current law, the ITC will remain in effect through December 31, 2016.

and in certain cases may extend 25 to 30 years. SunRun and SolarCity are examples of companies in the US that are providing the solar residential PPAs described in Figure 13.[35]

In the past, the only way for Utilities to benefit from the ITC would be through PPAs with solar developers. Since 2010, however, utilities can access the ITC directly causing some to no longer use third party PPAs. The reason why some utilities continue to function through solar developers is to leverage their technical expertise. Also, the PPAs "swap" certain economic risks to third parties. Those who invest in ownership of a PVHS are helping to mitigate the utilities risk of cost overruns and plant availability among others. In return the PVHS owner receives price certainty.

In the US, state and local governments have adopted the solar developer model for post offices, schools, police stations, court buildings and so on. These solar PV systems have proven successful because these properties will be used for a long period of time and the public entities allow solar developers to have access to low interest public financing. What is currently being debated however is whether the state and local governments should allow the solar developer to use this type of financing to retire the debt. This public PPA model is currently the practice in nineteen States and Puerto Rico.[36]

2.2.2.1 Renewable Energy Credits (REC)

Renewable energy certificates or credits, in the US, are made when a renewable energy system produces electricity. The electricity and the REC can be sold together or unbundled. "RECs represent the environmental attributes of renewable energy generation ... A REC represents the generation of one megawatt-hour (MWh) of electricity from an eligible source of renewable energy."[37] RECs do not only account for carbon that was not emitted in electricity production but also account for the generation source (i.e. solar PV). This way a cleaner environment is created and competing technologies can evolve allowing for the most efficient to dominate the market. Similar markets are being developed worldwide, through the creation of securities that follow clean development mechanism (CDM) guidelines, a certificate or credit can be bought or sold. A clear winner in the REC/CDM market has yet to emerge.

RECs can be bought and sold on the open market so that energy generators can comply with local or state regulations demanding that they support renewable electricity, especially if they have not themselves installed renewable generating capacity. Other institutions such as corporations, universities or individuals can also buy RECs to claim that they have "offset" their carbon footprint. For example, if my household consumes 1 MWh per month, I could buy 12 RECs and say that my household is carbon neutral for the year. In other words my home's carbon footprint for the year is now zero. Corporations or universities who want to appear environmentally concerned (i.e. Whole Foods, Intel and the University of Pennsylvania) can calculate the energy consumption of their buildings and buy RECs to offset their carbon footprint. Once an organization claims a REC that organization must retire the REC to avoid double claims in the future. In the US a REC tracking system has been established to collect data on the emerging REC market. Australia, China and South Korea are developing a cap and trade model with CDMs. In the US, government agencies are obliged to increase their renewable energy consumption while institutions such as the EPA and the US Air Force have been the largest consumers of RECs in the past five years.

[35] 2010 Solar Markets Trends Report: DOE
[36] Database for State Incentives for Renewables & Efficiency (DSIRE)
[37] US Environmental Protection Agency (EPA)

2.2.3 Solar Lease - Decentralized

For those State governments that do not allow the use of PPAs in their jurisdiction, because of the tax ramifications, the creation of the customer solar lease exists. This mechanism works exactly as the PPA, except that the option of ownership by the home or property owner is not allowed. Therefore only the lessor, who owns and finances the PVHS, can benefit from the ITC and tax free income generated by the PVHS. In this scenario, the home or property owner (as lessee) pays to use the equipment, guaranteeing the cash flow remains constant regardless of variations in the electricity generated by the PVHS. The home or property owners are no longer purchasing power as in the PPA scenarios. In the event that more power is consumed than produced the lessee purchases the excess from the utility. On the other hand if more electricity is produced than consumed the lessee will earn credit in cents/kWh on their electric utility bill. There may or may not be a guarantee offered by the lessor of a minimum kWh the PVHS will produce. As payments from the lessee are constant regardless of the PVHS output there is the moral hazard that the lessor will underperform on maintenance. Also, as leases are usually short term contracts and the maturities on borrowed capital is long term the risk of not having the sufficient clients at any point in time to pay obligations is high. In terms of public entities using solar leases, the client risk is mitigated given public entities have a low probability of canceling the lease. On the other hand residential or commercial clients have a higher risk of canceling and do not share the same tax-exempt status on their leases as do public entities.

2.2.4 Property Assessed Clean Energy (PACE) Programs - Decentralized

Property assessed clean energy programs allow for the creation of special tax districts so that private property that wishes to install PVHS can do so through property tax assessments. The Berkeley Financing Initiative for Renewable and Solar Technology (FIRST) pioneered Property Assessed Clean Energy (PACE) financing. This model allows financing to private property owners through electing a program whereby they agree to pay for an additional line item (i.e. school tax, municipal tax etc.) on their property tax bill. "PACE is a financing tool that allows municipalities to sell bonds, the proceeds of which would allow property owners to pay up-front for renewable energy and energy efficiency retrofits. A participating owner would accept a low-interest tax assessment on the property, thus spreading out the reimbursement and still allowing the owner to sell the property (transferring the assessment and capital improvement) without losing the investment."[38] Assessments allow a property owner to pay off "debt" in installments over a long period of time, however PACE is not legally considered to be a loan. Payments are typically made semi-annually and if the property is to be transferred all assessments must be settled beforehand; extra taxes are paid in full, however home or property improvements are accounted for in the valuation of the home or property. It was thought that the municipal bonds generated by this model could be sold as a new category of municipal bond. This thought was quickly extinguished after the commercial credit market slowed down in 2008 and home mortgage lenders were forced to re-evaluate their assets. PACE would legally allow a home mortgage lender's priority for reimbursement to decrease as the PVHS "loan" would be defined as a tax or an assessment and not as a loan in violation of mortgage lending practices in the US. Fannie Mae and Freddie Mac determined that they would not purchase mortgages with PACE "loans" thereby making it a viable option only for solar PV systems in commercial and non-residential spaces.

[38] The PACE Assessment Protection Act of 2011, 2599 House of Representatives § 2599 (House of Representatives 2011)

2.2.5 Energy Saving Performance Contracts (ESPC) – Decentralized

In the UK there exists a model called energy saving performance contracts (ESPC). In this model the solar developer installs a PVHS, at no upfront cost to the homeowner, in return for feed-in tariff (FIT) payments from the government. FIT payments can equal approximately £1,000.00 per year for 25 years. In return for the homeowners willingness to "rent" their roof, the homeowner receives energy saving (from an average 2.5 kW PVHS) of around £140 per year. The catch, however, is that when the homeowner wishes to sell the home he or she must obtain the written approval of the PVHS owner. If the homeowner pays for the PVHS upfront, he or she receives both the energy savings and annual FIT payments, breaking even in five to ten years and continuing to benefit from the remaining time offered on the FIT.[39]

2.2.6 Equity Solar Programs (ESP) – Centralized

Utilities and third parties are developing solar PV systems using the interest and support of the community. As consumers of grid electricity are interested in purchasing electricity generated by renewable energy systems the utilities created green pricing programs. With ESPs equity holders receive the benefits of the energy that is produced by their share of a solar PV system. In Jebel, Colorado a 80 kW PV system titled Holy Cross Energy has eighteen equity holders who purchased shares at an upfront cost of USD 3.15/W (USD 3,150/kW). In return the shareholders receive a USD 0.11/kWh dividend for electricity produced by the PV system every month. The dividend appears as credit on the shareholders utility bill every month.[40] The utility is able to support this type of arrangement as environmentally conscious consumers demand their energy be produced via a renewable source. In exchange consumers are willing to pay a premium per watt through what is known as a green pricing program.

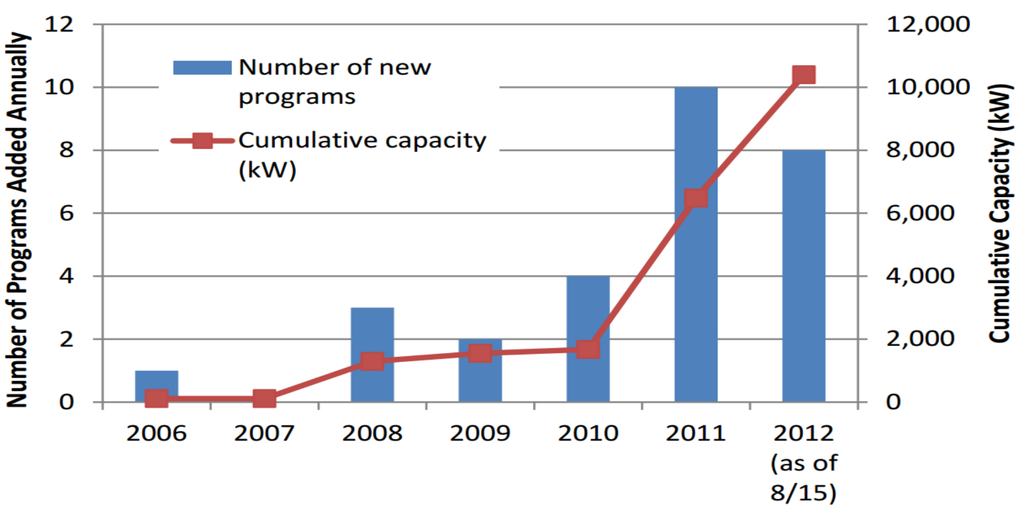


Figure 14: Number and Cumulative Capacity of Equity Solar Programs: 2006–August 2012.
The high upfront costs of owning PVHS have led to the creation of ESP. The ESP is a centralized PV solar system where members of a community can buy shares (usually denominated in USD/kW) and receive dividends from their local utility for energy production. The number of new programs added annually is growing as ESP become more popular.
Source: NREL

The ESPs benefit from economies of scale as larger installations enjoy lower installation costs, thereby lowering the cost per kW. The equity owner can buy and sell their home within the utility service area without needing to transpose or risk taking a loss on the investment capital. In the ESP model the equity holder does not need a physical space to host the system, yet benefits from

[39] Hughes, Emma
[40] Heeter, Armstrong, Bird

producing solar PV electricity. This model allows all utility customers to take advantage from the benefits offered by the green pricing program. "In 2011, 10 programs were introduced, and as of August 2012, an additional 8 programs had begun in 2012."[41] The combined capacity of all ESP is around 11 MW; the number of programs added annually has been growing rapidly. Figure 14 illustrates the number of new ESPs added annually and the cumulative capacity in kW over the past six years.

In circumstances where the ESPs qualify for various benefits, such as dividend exempt income tax and content multipliers (depending on local regulations), the dividend can go up to USD 0.54/kWh. Each equity holder must fulfill eligibility requirements to receive dividends; the dividends are capped at USD 5,000 per year per participant. Local governments have passed legislation requiring utilities to purchase REC from ESPs, similar to the PPA model. For example, in the state of Colorado, "Xcel Energy, will offer a new *SolarRewards*™ Community incentive program … under this new program Xcel will accept 4.5 MW of community solar (ESP) electricity in 2012; it will pay $0.14 per kWh for small programs (10-50 kW), and $0.11 per kWh for medium programs (50-500 kW), then scaling down the payments over time after 3 MW of capacity has been installed. Community solar developers were invited to submit applications on August 15, 2012, and Xcel closed the application process after 30 minutes, as three times the 2012 capacity allotment had been submitted."[42]

2.2.7 Solar Brokers

Recently, there has emerged what can only be called, a solar broker. The solar broker is a private enterprise model, which was created by One Block Off the Grid. One Block acts as an intermediary between potential PVHS buyers and solar installers, similar to car salesmen, security brokers or real estate brokers. The company identifies potential PVHS customers; later provides information on solar options; finds and evaluates installers on behalf of the customers; finally they add value through obtaining bulk pricing for the PVHS by harnessing community interest. By amassing the demand within a region solar developers create bargaining power that allows them to profit from installation cost savings. One Block is offered cents per watt installed, by the solar developers, for bringing new customers to use their services. The fee is built into the price of the installed PVHSs, however, is offset by the price savings obtained from customers buying in volume. The One Block model share similarities with the discount website Groupon that offers deals to groups of consumers in a specific geographic area, purchasing an identical product or service. As to the follow through of the solar broker, once a contract is signed, not much is known apart from the customer testimonials on their website http://1bog.org/.

2.3 PVHS Financial Models

[41] Heeter, Armstrong, Bird
[42] Heeter, Armstrong, Bird

As has been often mentioned, owning a PVHS is costly, in relation to average incomes in Portugal or the US. Financing is necessary to complete the purchase of a PVHS, similar to a home or automobile. Regardless of these high upfront and financing costs we know that the annual number of residential sector installations, in the US, is much higher than non-residential or utility solar PV (Figure 15). It is important to create a standardized financial investment vehicle such as a mortgage or car loan for the acquisition of PVHS. If successful, a clear market where PVHS loans or mortgages could be securitized and traded would be created and interest rates could be further reduced. At the turn of past century mortgages were not bought and sold at the same volume as railroad bonds. This caused that the average rate of interest on the railroad bonds in 1890 to be 4.36 percent whereas mortgages on average were around 6.73 percent. "The first company to issue debenture bonds secured by mortgages deposited in trust seems to have been the Iowa Loan and Trust Company of Des Moines, Iowa, which made its first issue in 1881."[43] In the past 131 years technology has advanced significantly and I believe that decentralized power generation loans, with the right financing model, can become as conventional as residential mortgages or car loans. Financial innovation and technological innovation work hand in hand. I propose that through the issue of debentures in the commercial credit market, retail banks could offer PVHS loans or mortgages to homeowners. A central regulatory authority, the Solar Energy Financing Authority (SEFA), would be created to administer the PVHS loans or mortgages by holding the cash flows produced by the PVHSs, in trust, and make timely repayment of loans.

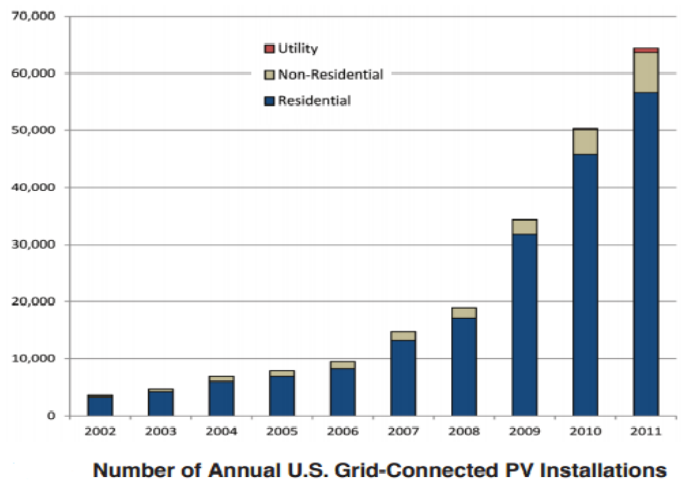


Figure 15: Number of Annual US Grid-Connected PV Installations by Sector (2002-2011).
Although in terms of capacity (MW_{AC}) residential and utility-scale solar PV installations are equal, in terms of volume there are many more PVHS installed per year than utility-scale projects.
Source: Sherwood, Larry US 2012 Annual Update and Trends Report

The PVHS financing model I am proposing is a low interest loan or mortgage to homeowners for the purchase of a PVHS. Investors in PVHS-backed securities would be parties interested in taking a large capital exposure to borrowers with low repayment risk, however, aware that a possible fall in electricity prices would place their capital at risk. If energy prices fall PVHS owners could purchase energy more economically from the grid and could stop payment. Also, my proposed financial models depend, partly, on energy savings to repay the borrowed capital. If energy prices fall therefore savings fall threatening the repayment of borrowed capital. The risk of energy prices falling however is mitigated by environmental regulations becoming stricter, favoring renewable

[43] Frederiksen, D. M.

energy power producers. The PVHS, once installed, produces electricity and hence is secured by a monthly minimum payment. The PVHS is guaranteed to generate this minimum payment by either the homeowner or the utility. Regardless of whether the debtor pays his monthly electric consumption or not, the PVHS produces electricity which is sold and whose benefits are collected by SEFA. As the benefits are dynamic, SEFA would administer the FITs, PPAs, RECs and other benefits that currently operate in favor of residential, decentralized energy producers to payback creditors. SEFA would receive an administrative fee, 0.5% – 1.5% of the interest on financing secured in the commercial credit market for the PVHS, similar to a mortgage service company.

The breakeven point for the PVHS, in our example, is around ten years. I would suggest allowing for PVHS financing of thirty years. A longer maturity on the financing will be used as the life of the asset is 30 years; components of the PVHS are guaranteed for ten to thirty years; PPAs can be negotiated for ten to thirty years. Given the steady rise in the price of electricity it is safe to assume that the debtor will have more income to pay his obligations, given the savings a PVHS offers in the long run. The longer maturity, high volume of PVHS loans or mortgages, in combination with a lower discount rate would allow the PVHS loans or mortgages to receive a lower interest rate than conventional loans for home improvements, real estate or even automobiles (none of the latter considered an investment that produces a daily cash flow).

2.3.1 PVHS Mortgage

I propose that the creditor offer two options to the debtor. The first option being a PVHS Mortgage similar to Energy Mortgages described above. The homeowner could choose to install a PVHS on his or her home and add the cost of the PVHS to his or her existing mortgage. Similar to the Energy Mortgage, the value of the property would rise along with the mortgage. What would change is that now private mortgage institutions could offer this product without the USD 8,000 cap and thus able to finance the whole PVHS. Monthly payments would be made by SEFA not the homeowner. SEFA on behalf of the homeowner would pay down interest and principal to the lender at the rate of savings and benefits the PVHS would generate. The risk that the cash flows produced by energy savings would be insufficient to pay down the mortgage would depend on the conditions offered in Lisbon or San Diego. In Lisbon a PVHS owner is guaranteed a rate of USD 0.287 per kWh produced for up to 50% of their annual electricity consumption. In San Diego the plethora of benefits offered by CSI and local utilities reduces the risk of non-payment from lack of energy savings to zero.

Electricity produced by the PVHS will be consumed in part by the homeowner and sold onto the grid. The PVHS being studied herein, as well as the cities, have the capacity for self-consumption and distribution. The risk that cost savings would be insufficient to repay the mortgage falls on the lender; however, there is a simple way for the lender to determine whether or not the PVHS being financed is capable of meeting the required payments. Using the variables from Figure 11 and a PVHS Mortgage of 30 years on USD 20,240.00 at a rate of 4.25% I will demonstrate one such method lenders may use. Figure 16 details the cash flows of a PVHS Mortgage, functioning in Lisbon, on the specific PVHS that is being studied. The PVHS Mortgage would require a payment of USD 100.52 a month for 30 years. The electricity produced by the PVHS is 500kWh per month in the first year, producing less over time as the PVHS degrades. It is assumed that 250kWh will be consumed by the homeowner and 250kWh will be sold at the EDP guaranteed rate of USD 0.287 per kWh onto the grid. The estimated savings therefore is USD 30.22 per month and the estimated income is USD 71.71 per month totaling USD 101.94. The EDP guaranteed rate (PPA) is only for 10 years however, I assume the same rate for 30 years; I did this because, I assume in 10 years the cost of electricity will be at least USD 0.287 per kWh if not greater.

Year	Debt Interest Payment($)	Debt Repayment ($)	PVHS Savings ($)	PVHS Income ($)	PVHS savings - Debt Repayment ($)	PVHS income - Debt Interest Payment($)	Energy (kWh)	Energy Value at EDP 0.287 Rate($)
1	860.2	346.07	362.7	860.57	16.63	0.37	5,997	1,721.28
2	845.49	360.78	362.7	860.57	1.92	15.08	5,949	1,750.19
3	830.16	376.11	362.7	860.57	-13.41	30.41	5,902	1,779.60
4	814.17	392.09	362.7	860.57	-29.39	46.40	5,855	1,809.49
5	797.51	408.76	362.7	860.57	-46.06	63.06	5,808	1,839.89
6	780.14	426.13	362.7	860.57	-63.43	80.43	5,761	1,870.80
7	762.03	444.24	362.7	860.57	-81.54	98.54	5,715	1,902.23
8	743.15	463.12	362.7	860.57	-100.42	117.42	5,670	1,934.19
9	723.46	482.8	362.7	860.57	-120.1	137.11	5,624	1,966.68
10	702.95	503.32	362.7	860.57	-140.62	157.62	5,579	1,999.73
11	681.55	524.71	362.7	860.57	-162.01	179.02	5,535	2,033.32
12	659.25	547.01	362.7	860.57	-184.31	201.32	5,490	2,067.48
13	636.01	570.26	362.7	860.57	-207.56	224.56	5,446	2,102.21
14	611.77	594.5	362.7	860.57	-231.8	248.80	5,403	2,137.53
15	586.5	619.76	362.7	860.57	-257.06	274.07	5,360	2,173.44
16	560.16	646.1	362.7	860.57	-283.4	300.41	5,317	2,209.96
17	532.7	673.56	362.7	860.57	-310.86	327.87	5,274	2,247.08
18	504.08	702.19	362.7	860.57	-339.49	356.49	5,232	2,284.83
19	474.23	732.03	362.7	860.57	-369.33	386.34	5,190	2,323.22
20	443.12	763.15	362.7	860.57	-400.45	417.45	5,149	2,362.25
21	410.69	795.58	362.7	860.57	-432.88	449.88	5,107	2,401.93
22	376.88	829.39	362.7	860.57	-466.69	483.69	5,067	2,442.29
23	341.63	864.64	362.7	860.57	-501.94	518.94	5,026	2,483.32
24	304.88	901.39	362.7	860.57	-538.69	555.69	4,986	2,525.04
25	266.57	939.7	362.7	860.57	-577	594.00	4,946	2,567.46
26	226.63	979.63	362.7	860.57	-616.93	633.94	4,906	2,610.59
27	185	1,021.27	362.7	860.57	-658.57	675.57	4,867	2,654.45
28	141.6	1064.67	362.7	860.57	-701.97	718.97	4,828	2,699.04
29	96.35	1,109.92	362.7	860.57	-747.22	764.22	4,790	2,744.39
30	49.18	1157.09	362.7	860.57	-794.39	811.39	4,751	2,790.49

Figure 16: PVHS Mortgage Cash Flows for PVHS of 4kW in Lisbon, Portugal.
The PVHS Mortgage would require a payment of USD 100.52 a month for 30 years. The electricity produced by the PVHS is 500kWh per month in the first year, producing less over time as the PVHS degrades. It is assumed that 250kWh will be consumed by the homeowner and 250kWh will be sold at the EDP guaranteed rate of USD 0.287 per kWh onto the grid. The estimated savings therefore is USD 30.22 per month and the estimated income is USD 71.71 per month totaling USD 101.94..
Source: David N. Pereira

A more detailed accounting of this specific PVHS can be found in Appendix 7. In the PVHS Mortgage model, the monthly payments that the homeowner makes will be for the full amount of their electricity bill. However, instead of paying to their local utility (i.e. EDP) they will pay to SEFA. The debtor will continue to pay his bills as if he had not installed the PVHS. SEFA will then calculate the energy income as well as the energy savings incurred by the PVHS: the difference between total energy consumed and the energy produced by the PVHS. Currently, the only benefit for PVHS owners in Lisbon, Portugal is the PPA offered by EDP. Therefore, it will be necessary for the PVHS owner to sell half of his production onto the grid. After SEFA accounts for all benefits (tax, tariff, REC, PPA and other that may apply) and costs (administrative fees and others that may apply) of each household, SEFA repays the creditor (commercial credit market) as well as the utility. If the utility sold electricity produced by the PVHS on the grid the utility will pay SEFA, in the account of the PVHS owner, and SEFA will make the creditor whole. If the homeowner moves or sells the property the PVHS will be transferred to the new home, sold with the home or sold separately at a discount to an ESP.

From the point of view of the commercial credit market, the PVHS mortgage will be viewed as a "floating repayment" with a floor and no ceiling, as the PVHS will generate electricity that will be bought and sold, regardless of if it's on the grid or to the PVHS owner. The term of the mortgage will be more than ten years so that it fulfills the repayment of principal and interest. Only after ten years will the debtor have the option to pay down the PVHS mortgage at an accelerated rate or in totality. Finally, the interest rate could be higher on this option so as to compensate creditors for uncertainty in the repayment schedule.

2.3.2 PVHS Loans

In the second scenario the creditor can offer a PVHS loan similar to a car loan. However, instead of focusing on if the make, model and year of the car are suitable to the borrower; the lender would be concerned with if the geography, weather and component mix of the PVHS is suitable to the borrower. I suggest that PVHS loans could be made at a fixed rate of 4.25 percent or lower. When the PPA model is used to install a solar PV system on a public building the municipal government issues bonds to fund the installation. The most recent municipal bond that was issued (New Jersey, November 2012) had a rate of 3.75 percent and a term of 15 years. The solar developer, who installs the solar PV system and is responsible for the repayment of the municipal bond, would not be able to obtain such favorable financing on their own. It should be noted that the full faith and credit of the community is what is guaranteeing the municipal bond and has allowed for such a low rate of financing. As the PVHS loan will be offered to individual members of the community and there is a longer maturity, I assumed a premium of 50 basis points hence a 4.25 percent interest rate for PVHS loans.

Unlike 'secured' car finance agreements, such as hire purchase or leasing, the PVHS loan will mimic car loans. Therefore it will be considered to be 'unsecured', which means that the finance is not secured against an asset (such as the PVHS or car being bought). As such, the homeowner, not the finance company, will be the outright legal owner of the PVHS. The risk that the cost savings will be enough to repay the loan will fall again on the finance company. However, to compensate for this risk all the cash flows and savings incurred by the PVHS will belong to the finance company until such time that the debt is settled.

SEFA will be responsible for collecting the monthly electricity and PVHS loan payments from debtors. The saving incurred every month will create a micro sinking fund for the PVHS loan consumer, along with the benefits received (tax, tariff, REC and others that may apply) minus costs (administrative fees and others that may apply). The debtor will make monthly payments on the PVHS loan knowing that the benefits from owning the PVHS are being collected in a sinking fund. The debtor can settle the PVHS loan at any point in the contract by settling the outstanding balance with the lender. A personal loan agreement will naturally end when all repayments have been made over the duration of the agreement. Lenders will disclose all additional fees and charges that may apply in the terms and conditions of the PVHS loan before the agreement starts. The way the PVHS loan agreement is written should allow the debtor to pay installments until there are enough funds in the sinking fund to pay the principal or until he or she decides to pay the PVHS in full. At such time, all future benefits of the PVHS belong to the homeowner.

Currently, a homeowner can lease a PVHS or pay for the PVHS out of pocket; however, there is no model that allows for a homeowner to obtain a low interest loan specifically for the purchase of a PVHS. PVHS loans are important as they allow for the homeowner to receive all benefits of ownership and after paying back the creditor ownership of the PVHS. The risk in the PVHS loan belongs to the creditor, again, if energy prices fall and energy savings from the PVHS are limited repayment could become problematic. However, given current political and societal shifts in preferences for energy generation and consumption this risk is being mitigated by policy in favor of decentralized solar PV energy generation.

In the next section I will review some of the current mortgage and loan models that are used in the US and demonstrate how they relate to the PVHS mortgage and PVHS loan. This will also help to establish benchmarks and a framework as to how these products should function.

2.3.3 Implications of PVHS Financing Models

A successful financial model for PVHS depends on making the internal rate of return (IRR) numbers work with a high degree of predictability for commercial credit institutions in the short term and homeowners in the long term. The only predictable revenue streams will be payments for electricity under long term PPAs or repayments in the PVHS loan model. Production based initiatives will prove beneficial in smoothing cash flows by providing an additional revenue stream such as the California Solar Initiative and other State and city initiatives in the US, effectively creating a floor or minimum stream of cash flow so long as the PVHS is functional. The ability to finance large utility scale projects by IPPs remains difficult because of the PPA pricing, the size of projects, transmission line improvement requirements, site selection, technology risks, environmental approvals among other factors. It is currently the solar PV industry view that the best business model is to build, own and sell power to a utility once the system is on-line and residential homes can make this happen faster, with more diverse risk and without as many hurdles as IPPs or utility sized PV owners.

In both scenarios described above the PVHS would ultimately be the property of the homeowner so that they might receive all the benefits afforded through ownership of the system. Until such time as the PVHS is paid for in full all energy savings and cash flow of the PVHS belong to the creditor until the PVHS loan or mortgage is paid in full. The cash flow produced by the asset and savings will be the economic property of the creditor, the residual claimant. If the PVHS were to be paid in full, the PVHS mortgage or loan is settled, the energy savings and all the benefits of the PVHS revert to the homeowner. The creditor, through SEFA, is guaranteed a minimum payment as long as the system is operating. The guarantee is provided by the utility who is obliged to buy the excess energy and RECs; in other situations the guarantee is provided by the government or utility (i.e. CSI) who pay for a portion of the PVHS (the upfront capital will be administered by SEFA to pay down the PVHS loan or mortgage); in other situations the guarantee is provided by the homeowner who upon entering the PVHS loan or mortgage agreement will continue to pay their electricity bills in full. In the last situation described the homeowner technically enters into a PPA with themselves by agreeing to use their energy savings and other benefits to pay down their obligations.

In comparison to a tradition loan for the purchase of a PVHS, the method being proposed creates an element of financial sophistication which gives both borrower and lender extra utility. The lender can now make a PVHS loan or mortgage with more information and greater certainty of how it will perform in the future without having to rely on credit scores or distress about downturns in the economy. This product is not for all geographies or for all technologies so lenders are not only protecting themselves but consumers as well by approving or declining PVHS loans or mortgages. Using the PVHS loan or mortgage the lender has more protection against default by the homeowner than in a traditional loan. As long as the PVHS is operational, it produces renewable electricity which is desired by utilities for consumption on the grid. More importantly to lenders, the asset is producing a constant cash flow something that is not accounted for in a traditional loan for a PVHS. In exchange the borrower receives a lower interest rate as it is not he or she that is being scrutinized for the loan but rather the PVHS itself. Through SEFA both the lender and borrower are being protected as they are informed and benefit from all remunerations offered to PVHS owners. Unlike traditional loans for PVHS, with PVHS Mortgages and Loans there is an agency collecting all the electric utility payments and benefits so that the borrower can settle as quickly as possible.

The installation, operation and maintenance of the PVHS would be similar to a home or car and the responsibility would fall on the homeowner. In both scenarios the homeowner has the largest incentive to keep the PVHS efficient. At any time if the PVHS owner using the loan model becomes delinquent he or she will automatically be shifted to the PVHS mortgage model after a three month grace period, something that is unheard of if the borrower takes out a traditional loan to finance the PVHS. All of those who took on PVHS loans or mortgages that can no longer host the PVHS or are no longer interested in owning a PVHS due to circumstances can have the option to sell their system to an ESP if one is available in their community or a green pricing program is provided by their utility. Therefore the PVHS Loan or Mortgage is more liquid than a traditional loan.

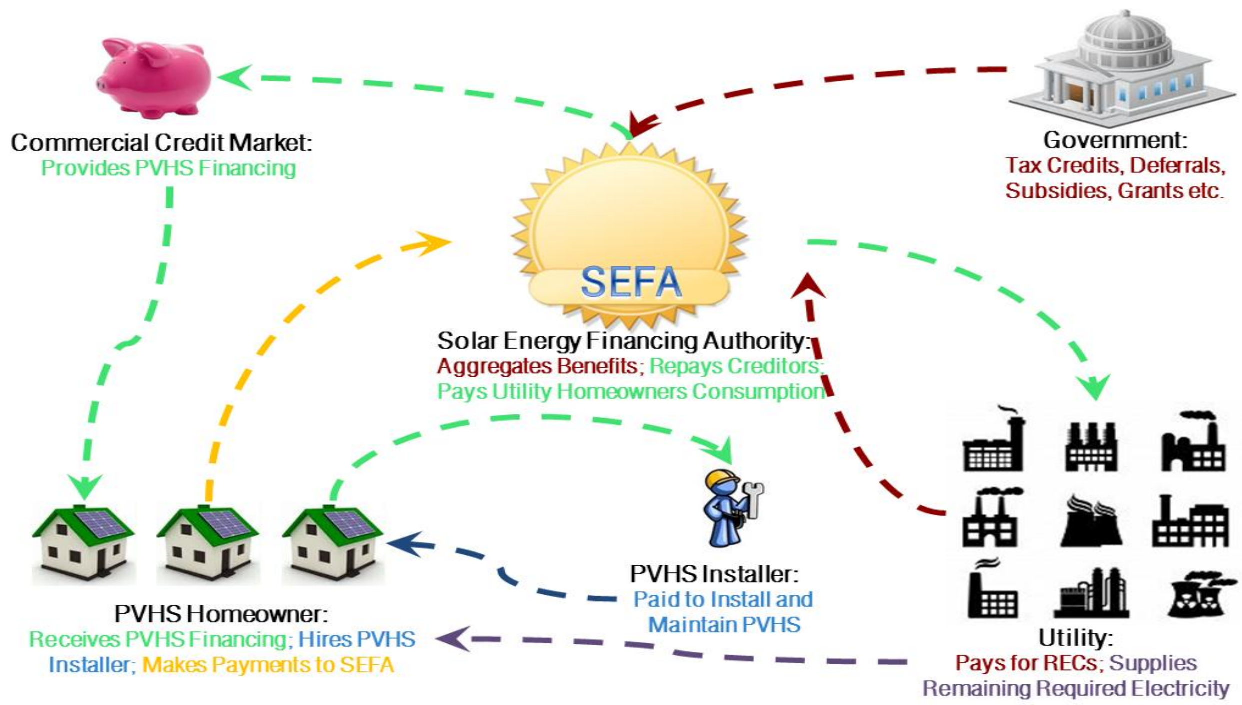


Figure 16: PVHS Proposed Business Model.

Unlike the Solar Developer PPA model the PVHS Proposed Business Model affords all benefits (IRS, REC and others) to the Homeowner. The Commercial Credit Market provides the PVHS Loan or Mortgage to the PVHS Homeowner => The PVHS Homeowner hires a PVHS Installer to install and maintain the PVHS => The PVHS Homeowner then makes monthly electricity and/or loan payments to SEFA => SEFA aggregates the benefits provided by the Government, Utility and other institutions and repays the Commercial Credit Market and the Utility => The Utility then supplies the remaining electricity required to the PVHS Homeowners.

Source: David N. Pereira

Figure 17 is a flow chart representation of the players involved and the interaction between them in a PVHS Mortgage or Loan scenario. The Commercial Credit Market provides the PVHS Loan or Mortgage to the PVHS Homeowner => The PVHS Homeowner hires a PVHS Installer to install and maintain the PVHS => The PVHS Homeowner then makes monthly electricity and/or loan payments to SEFA => SEFA aggregates the benefits provided by the Government, Utility and other institutions and repays the Commercial Credit Market and the Utility => The Utility then supplies the remaining electricity required to the PVHS Homeowners.

The PVHS mortgage has a "floating" repayment schedule so that the creditor has an unknown stream of revenue; repayment is dependent on power generated by the PVHS and energy savings. To compensate the creditor for the uncertainty in the repayment schedule the interest rate may be higher. The PVHS loan will have a "fixed" repayment schedule. Regardless of the energy produced or consumed the debtor will have to pay a fixed amount of interest each month. In return for the certainty in payments the interest rate in the loan scenario will be lower than in the mortgage scenario. In both cases the homeowner is taking advantage of all benefits that might apply to residential solar PV owners including tax credits, PPAs, FITs, RECs, grants as well as any future or other applicable benefit to pay down their obligations. SEFA will be paid an administrative fee to ensure that the PVHS owner benefits from all applicable incentives provided by the local utilities, local, municipal, state and federal government so as to repay the PVHS loan as soon as possible with the lowest cost to the homeowner.

2.3.1.1 Households

The PVHS loan and mortgage if formalized and standardized will offer households the ability to generate their own electricity and make an investment that will afford savings hence increase disposable income in the long term. The large upfront cost of owning a PVHS will be absorbed by the creditor and all the benefits afforded to PVHS owners by government and REC markets will benefit households in the long term. The household will have invested in a revenue producing good which can pay for itself over time as long as energy is being produced and consumed. In exchange, the PVHS debtor continues to pay his or her electricity bills as per usual knowing that in the future the PVHS will be repaid and the homeowner can benefit from energy savings for the balance of the life of the asset.

2.3.1.2 Banks and Credit Unions

The commercial credit market through banks or credit unions can work to create a standardized PVHS loan and mortgage. The cash flows generated by an operational, grid connected PVHS asset would act a guarantee against the PVHS loan or mortgage. In the worst case scenario the bank would be able to sell the PVHS to an ESP (community solar program) thereby being made whole. Similar to when a debtor fails to meet their obligations in project finance, the creditor is entitled to the cash flows produced by the PVHS. The bank or credit union would need to create a standard fiscal review of prospective borrowers, similar to mortgage consumers, however instead of having to check borrowers banks and credit unions could work with agencies like SEFA to determine what a suitable component mix (of the PVHS) might be for certain geographies, weather patterns and socio-economic borrowers. The volatility of the repayments will depend on if the financing is a PVHS loan or mortgage as previously mentioned. It is my opinion that politically the buy in of credit unions is essential to standardize PVHS financing; some credit unions are more informed about their communities and could have more experience in constructing guidelines for PVHS loans and mortgages (as was the case in the early US residential mortgage market). PVHS financing is intended to be as simple a transaction as a car loan or home mortgage.

The risk profile envisioned for PVHS financing is low thereby allowing for lower interest rates to be offered by the bank or credit union. Credit risk will be considered low; SEFA, acting as custodian between the cash borrower and the cash lender, will prevent the borrower from using future cash flows provided by the PVHS to pay current debts. The borrowers' overall ability to repay is based on their consumption of electricity (or potential sale of electricity if they are not consuming) making it very likely the bank or credit union will be repaid. The borrowers' collateral assets for the PVHS financing will be the PVHS, its cash flows and auxiliary benefits. As the financing will be for a revenue-generating asset with a long term contract the credit risk is further reduced. In many cases the federal, state and local taxing authorities offer benefits to PVHS investments made by individuals. Banks and credit unions might be able to offer lower interest rates as they will be exempt from taxes as will those who finance PVHS loan and mortgages. Interest rate risk can be low to medium as the maturities of the PVHS financing will tend to be between five to thirty years. This risk can be managed by banks through interest rate swaps and debt management (i.e. managing maturities offered). The risk that electricity prices might fall in the future, I believe to be, very low as energy prices continue to rise and inflation continues to grow in Europe and the US.

The liquidity risk or limitations will be those associated with homeowners paying their utility bill on time. As homeowners constantly need to consume electricity the probability that they will be delinquent is low. Utilities are considered to be vital institutions and have access to capital through the municipal bond market. The probability that utilities will not follow State legislation, not honor their contracts with PVHS owners or run out of liquidity is also low. The risk related to external factors such as weather, catastrophic events and the like is one that can be lowered through home insurance, which covers the PVHS. Finally, as these would be considered a new debt instruments the risk related to structure and performance would be initially high. Over time this risk would be lowered as the market becomes established and products are standardized. Public and private institutions working together to shape SEFA is clutch to the proper operation and success of the PVHS financial models.

2.3.1.3 Economy

Depending on how the market is shaped by policy and the will of the population to adopt PVHS the effects on the economy could be positive. I believe that demand for electricity will rise in the future. PVHSs provide a supply of electricity that helps make households and countries less dependent on foreign energy. We also know that as GDP increases so does electricity consumption.

PVHSs could potentially contribute to:

- increased GDP
- greater household productivity
- more educated consumers
- lower inflation
- increase in long term savings
- market stability through low risk investments
- decrease in international energy reliance

PVHS financial models would allow for homeowners to increase the value of their properties whose mortgages are currently lacking liquidity. Through improving the home mortgages underlying asset with a capital injection from an alternative market the mortgage industry could begin to regain balance and market confidence. If we assume that an average home can install a 4kW PVHS at a cost of USD 20,240.00, the current market size for PVHS financing in 2011 was USD 5.06 billion (1,000 MW installed in 2011, which equals 1,000,000kW/ 4kW = 250,000 PVHS x $20,240.00 per PVHS). Although this would constitute but a drop in the bucket of the more than 10 trillion USD mortgage market, a standardized financial product sold through credit unions or savings and loan institutions could have a much larger impact.

Finally, decentralized power generation compliments large scale energy transmission, in the capital markets, as economic substitutes. PVHSs allow for investments to be made in new technologies thereby allowing for growth in the US economy (according to Solow growth model). Portugal's economy has also shown that it too responds positively to innovation and technological advance and Portugal is a world leader in renewable energy generation.

2.3.1.4 Securitization of PVHS Loans

If a critical mass of PVHS financing is used and perceived as a low credit risk instrument a market similar to mortgage backed securities (MBS) could form. PVHS loans can be bundled into pools of debt which allow for periodic interest payments to pass through to investors; PVHS mortgages can be bundled and categorized by class similar to MBSs. These bundles could prove useful in the creation of a new type of interest rate swap. PVHS could even grow to be seen as a "hedge", in decentralized energy production that provides an investment pool of low credit risk capital, against large scale energy transmission.

The credit risks in MBSs arise from the difficulty in smoothing the uncertainty in cash flow due to prepayment options and default. The assets underlying the PVHS financing are solar PV systems, not labor (which is subject to unemployment risk) as in home mortgages. PVHS will produce a positive cash flow over a long period of time with little default risk for 30 years (uncorrelated with the unemployment market). Eventually, households that hold mortgage debt and have a PVHS installed could increase their property valuations, leaving the debtors credit rating unchanged (due to higher income, due to energy savings, tax credits, excess power production and REC creation; as in the case of Energy Mortgages).

Alternatively, the creation of utility, city or state OTC markets to buy and sell ESPs would account for proper regulation of benefits and could be administered by SEFA. Individuals who are interested in participating in the benefits of solar PV energy production but do not qualify for PVHS (due to lack of a suitable roof, lack of private property, lack of cost effective climate and so on) can participate in ownership of centralized grid connected solar PV. There currently exists a marketplace in community solar programs whereby individuals residing in a specific utility zone can buy equity ownership of a solar PV system and receive monthly dividends from their investment. Through the creation of SEFA a precise figure of costs and benefits could be calculated for individuals residing in specific utility zones allowing for clear accounting of community solar programs or ESPs. Currently there exist a number of incentives for solar PV however the amount of information, monitoring and risk sharing is very low.

Mortgage Market

The modern definition of a mortgage according to Frank Fabizzoli, author of the Handbook of Mortgage-Backed Securities is, "a 'pledge of property to secure payment of a debt. Typically, property refers to real estate, which is often in the form of a house … Thus a mortgage might be a pledge of a house to secure payment of a bank loan. If a homeowner fails to pay the lender, the lender has the right to foreclose the loan and seize the property in order to ensure that it is repaid. The form of a mortgage loan takes could technically be anything the borrower and lender agree upon."[44]

The debt portion provided by the commercial credit market for the mortgage is structured so that the total monthly payment is levelized to the sum of the principal and interest of the debt. Therefore monthly payments equal the interest rate times the mortgage balance at the beginning of the month making the mortgage balance the amount of the house value the home buyer does not yet own. Prepayments may apply and depending on the flexibility the bank is capable of providing in terms of late payments, the bank may foreclose on the loan and sell the property to be made whole on its investment.

3.1 US Mortgage Evolution

University of Chicago keeps data on what the nascent mortgage market in the US looked like at the turn of the 20th century. We are given examples of the size of the market in USD and the number of players in Appendix 5. Interest rates and maturities varied by region. In the East interest was around 5.25 percent (6 year maturity), in the South 8 percent (3 year maturity), in the central US 7 percent, in the West 8 percent (4 year maturity) and in the mountain and arid states above I0 percent.[45] It is estimated that the total mortgage indebtedness of thirty-three states and territories was USD 4,935,455,896.00 and for the entire US, in 1894, USD 7,100,000,000.00. Over 70% of these mortgages were held by private persons in the US. What is interesting to note is that less than two percent of all the mortgages in the US were held by a mortgage loan company, ten percent belonged to savings banks, seven percent belonged to the building and loan associations, five percent belonged to insurance companies, fifty-five percent belonged to local investors and eighteen percent belong to non-resident private investors[46].

Since 1894 we know that capital has become widely available through lending institutions which had formalized mortgages thus no longer requiring that an individual in a local community be the lender. This effusion of capital was necessary as the value of property kept growing, causing greater mortgage indebtedness and longer payback periods. "In the West this increase (in mortgage indebtedness) seems to depend on the facilities for borrowing, more than on anything else. The year when the greatest number of mortgages was recorded was I887, which was the very time when the newly organized Western loan companies were finding it easy to dispose of mortgages in the Eastern states."[47]

US agencies were developed to assist in extending mortgages such as The Federal National Mortgage Association (Fanny Mae), The Federal Home Loan Mortgage Corporation (Freddie Mac) and The Government National Mortgage Association (Ginnie Mae)

[44] Fabizzoli, Frank
[45] Frederiksen, D.M.
[46] Frederiksen, D.M.
[47] Frederiksen, D.M.

among others. The federal government in the US would offer funding support to savings and loan organizations as long as they followed certain uniform regulations and standards as determined by the Federal Home Loan Bank Board (FHLBB).[48] The Federal Housing Administration (FHA) replaced the FHLBB in 1934 and offered insurance against default risk for loans underwritten according to FHA standards. The creation of these agencies, the interest of the American people in owning their own home and the entrepreneurial spirit of catering to the demands of the masses began to allow for the standardization of financial models which would grow to incorporate various dimensions that would make them more appealing to investors and homogenizing mortgage contracts for the efficient operation of a secondary market.

The market has matured greatly in products to offer investors and customers since 1894. In 1984 there was more than USD 300 billion of residential mortgage debt "securitized" under two types of MBS issuances, mortgage pass-through (MPT), treated as a sale of assets, and mortgage backed bonds (MBB), treated as a debt obligation. More than 90% of the market in 1984 was comprised of MPTs; only about USD 20 billion was MBBs[49]. In total there was USD 1.526 trillion worth of single-family residential mortgages in 1985 which in 2010 had increased to USD 10.522 trillion according to the US Board of Governors of the Federal Reserve System. (Appendix 6)

Mortgage pools have been tailored to address the specific needs of institutional investors, such as insurance companies and pension funds. In 1985 two thirds of families in the US owned their own home, "(this) would not have been possible if long-term financing in the form of conventional mortgages had not been plentiful."[50] (Figure 18)

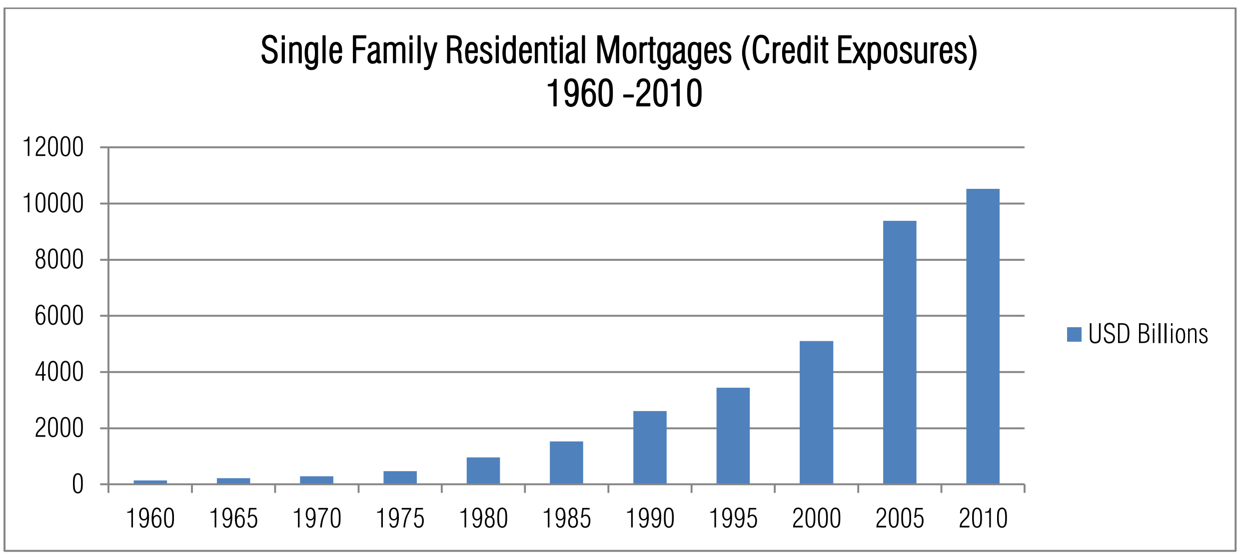


Figure 17: Single Family Residential Mortgages (Credit Exposures) 1960 -2010.
The growth of Single Family Residential Mortgage credit exposure in the past 50 years has been explosive. The most pronounced growth has been in the past 20 years and it is my belief that a similar growth can occur with PVHS Mortgages if a standardized product is accepted by the majority of financial institutions.
Source: Federal Reserve Flow of Funds Table L. 218

[48] Fabizzoli, Frank
[49] Fabizzoli, Frank
[50] Fabizzoli, Frank

3.2 Mortgage Securities

MPTs are highly favored as they were designed with federal supported entities providing both credit and standards of uniformity. The standardization allows for analysis and pools that can be resold to qualified investors. For example Government National Mortgage Association (GNMA) mortgages are sourced from FHA-insured and Veterans Association guaranteed mortgage loans, backed by the full faith and credit of the US government; Freddie Mac Participation Certificates are the second largest traded MPT (by volume and size) that deal single family residential mortgages without guarantees. Freddie Mac guarantees the timely payment of interest and ultimate payment of principal (with one year leeway in principal payments); Fanny Mae MPTs, guarantees the timely payment of interest and principal for all securities issued; Private MPTs can be issued without guarantees by independent companies such as commercial banks.

When an MPT is trading at a premium, an increase in prepayments occurred in the pool lowering the yield due to maturity risk. As the amount and timing of future cash flows will constantly change, it is assumed that mortgages have an average life of twelve years before a prepayment might occur calculating the conditional prepayment rate (CPR). This assumption has proven to work better in studying the past. Applying the CPR to PVHS mortgages the assumption that a constant fraction of the remaining principal will be prepaid each month and that each mortgage in the pool is equally likely to prepay could prove feasible. The simplicity of a CPR applied to PVHSs after analyzing data contingent on geography, weather patterns, SEFA, utilities and so on could prove favorable to less volatile prepayment conditions. Compared to Treasury yields of an equivalent average life (12 years) a breakeven prepayment rate is calculated; the cash flow yield of the MBS plus the yield required over 12 year Treasuries.

MBBs created a pay through vehicle similar to a MPT for the exception that the pay through was considered to be a sale of debt while the pass through constitutes a sale of assets. This MBS was used to provide more certainty of timing of cash flows and to attract funds at a lower cost than MPTs. Investor groups that needed tailored maturities or call protection could now qualify for MBS and issuers (who at the beginning were thrifts) could minimized the collateral required to support the issue while maintaining the integrity of the credit. In 1983 Collateralized Mortgage Obligations (CMO) allowed a pay through bond with three classes to be issued using only mortgages with Freddie Mac guarantees.

3.3 Comparison of PVHS and Residential Mortgages

Fabozzi in the conclusion of his study on the residential mortgage market in 1985 found that of the current financing models for residential mortgages, none could be considered a “satisfactory solution of the problem of mortgage banking.”[51] If the lenders need to be protected from risk and the borrowers from usury a PVHS mortgage, through scrutinizing the components and geography, could be the solution. Also, from the inception a European model of mortgage financing should be adopted for PVHS mortgages whereby bonds for PVHS mortgages will be able to be listed.

To be considered creditworthy, residential mortgage borrowers need to meet certain standards found adequate by the lender. For example, the income or net worth of the borrower must be considered adequate or sufficient; 25% of the borrower’s income should

[51] Fabizzoli, Frank

be available for mortgage payments; 33% available for mortgage payments, taxes, insurance, utilities and normal maintenance costs. If the borrower has other loans or obligations outstanding their creditworthiness diminishes. For a PVHS loan or mortgage a rule of thumb could be established whereby income or net worth of the PVHS equals 25% to 33% of the mortgage payments, on a yearly basis, ensuring the cost of the PVHS is suitable for the PVHS mortgage.

Usually mortgages today require a down payment of 5% to 25% of the value of the property so that a loan to value (LTV) ratio can be applied categorizing high and low credit risk investments (the lower the LTV the lower the loan amount relative to the property value). I propose that to have a greater adoption of the technology, no down payment need be made since the asset being financed is generating tax-free income. Already in the US there are a number of states which will subsidize up to 50% of any PVHS; if this is the case then a PVHS mortgage practice for that state might be different than one which does not subsidize PVHSs. In the future, so as to allow room for newer technologies, a down payment of 5% to 25% of the PVHS could apply. Although the PVHS will not grow in value the same way a property may or may not, the cost of energy will rise. If newer technologies such as electric cars are to ever be feasible energy generation must take a significant capital "step forward".

In 1985 capital for residential mortgages came primary from credit unions, also known as savings and loan banks. In the US these financial institutions are known as "thrifts" because the loans for the mortgages come from the accumulation of thrifty depositors. I propose that "thrifts", guided by SEFA, provide the capital needed to finance the first PVHS mortgages and loans. In the US at the beginning of the residential mortgage market we saw that the majority of mortgages were capitalized by individuals in the community where they were consumed. PVHS financing could adopt a similar evolution pattern. Later commercial banks, solar companies, insurance companies, pension funds, utilities, federal, state and local entities empowered to make loans can provide more capital. In the residential mortgage market the lender and owner of the mortgage are essentially one in the same while those who create mortgages are interlopers. This is why most mortgage bankers after creating mortgages look to immediately package and sell them. Solar developers are already adopting a model that is very similar to mortgage bankers which we know has suffered from a moral dilemma.

Current laws in the US are identical when categorizing properties that can be mortgaged. Residential for example applies to a one to four family homes, vacation properties and anything from a condominium to a mobile home. Non-residential properties can be commercial or farm properties and can be a hospital or shopping mall, a factory or office building.

PVHS mortgages could be structured to replicate Pledged Account Mortgages (PAM). Instead of putting 15% down on the property a consumer could put 5% down on the property and 10% in a savings account that earns interest and pays down the mortgage at the same time. Someone interested in a PVHS mortgage could tie a savings account to the mortgage as collateral and allow for the saving from the PVHS to compliment that savings account to create a larger upfront sinking fund, lowering the credit risk to the lender. This would create an instrument that blends a buy down loan and a PAM; the account created by SEFA for the PVHS owner will be segregated from the traditional savings account and used to augment the buyer's PVHS mortgage payments or pay down the principal at the end of the loan.

Discussion and Main Conclusions

This study's main finding is the cost-effectiveness of the specific PVHS studied both in San Diego, California and Lisbon, Portugal given the financing options discussed. The PVHS discussed in this paper for Portugal is estimated to produce 5,997 kWh/year of energy worth a minimum of USD 0.13 cents (in 2013, if the producer consumes *vazio*) or a maximum of USD 0.287 cents (if producer enters into a PPA with EDP in 2013). The PVHS financing would be for USD 20,240.00. If the PVHS sold only 50% of its production (income of USD 860.57) and saved the other half at *vazio* rates (savings of USD 362.70) the net amount that would reach SEFA without other benefits being added would be USD 1,223.27. Given an administrative fee of 1.15% (of interest) or USD 6.12 that needs to be paid to SEFA, the creditor would receive USD 1,217.15 which is 100.09% of the proposed financing of a PVHS 30 year Mortgage at 4.25%. The energy sold effectively covers the interest portion of the loan for the life of the debt (see PVHS income - Debt Interest Payment line; Appendix 7) and the energy savings covers the principal for the first two years where it is then balanced by the income and generates profit of USD 17.00. This study corroborates the findings of the California Public Utilities Commission for San Diego, California and the EPIA for Lisbon, Portugal whereby PVHSs are cost effective. The PVHS that is described in Appendix 9 & 10 is just one of many PVHS component mixes that might be used, and as technology advances and component prices fall the specific PVHS in this study will become ever more cost-effective.

The main contribution of this paper is the financial models developed so that ordinary individuals can choose to become energy generators. Homeowners, using these financial models, could now become energy generators benefiting the energy consuming public. Whether they consume the energy themselves or sell it they would be making social and economic contributions by producing a good which is consumed daily, and necessary to GDP growth. Financial institutions would invest in more sound investments with a guarantee of repayment while the environment would benefit from a more dynamic use of resources that lowers fossil fuel consumption. Currently, there are no business models for PVHS that give all the benefits of ownership to homeowners without homeowners paying all the upfront costs. The current business models that exist for PVHS are structured so that homeowners with capital can benefit from incentives, however average homeowners cannot. From the Matrix (I created to simplify the overview of the current business models) we can see that in all the current business models, the upfront capital needs to be invested by the homeowner if the majority of the benefits of the PVHS are to go to benefit the homeowner. What I am proposing is a standard mechanism to attract funds out of the capital market so that homeowners can take advantage of these benefits without large upfront costs. Non-technical factors such as the cost of electricity and rate structures are already favoring decentralized renewable energy generation; however, financing for PVHSs is lacking. If PVHS are ever to become the norm rather than the exception, a standard financial model to bear those capital costs must be implemented.

I argue that the financing alternatives presented here, PVHS Loans and Mortgages, are congruent with the homeowner consumption of PVHS. PVHS loans or mortgages allow for a predictable stream of payments through interest payments, electricity sales and/or energy savings. The lenders are protected as all cash flows from the energy generation of the PVHS belong to the creditor until the time when the borrower pays in full. In exchange the creditor agrees to lend the full upfront cost of the PVHS at a low rate over a long period of time (i.e. 4.25 percent over 30 years). The risk to the creditor is mitigated as long as the PVHS is running. PVHS financing can be a complement to all portfolios that are not currently invested in decentralized renewable energy and receive tax saving through carrybacks, deferrals, and other mechanisms. SEFA could match cash flows, durations, and re-pricing (rate-setting) frequencies in order to lower risk, create uniformity and reduce liabilities to investors. CPR could become reasonably predictable given weather patterns and geography so that instruments can be structured to match cash flows with liabilities.

I further argue that if a formal market of PVHS loans and mortgages is created and accepted as low risk, it would be possible to bundle a large number of PVHSs into partnerships so as to securitize them. A PVHS pass through could take a series of cash flows and dedicate a portion of them to predetermined holders who indicate a preference for cash flows in specific periods. The remaining portion of cash flows could be priced according to yield and prepayment effects given climate and geography. SEFA can provide the analysis required by the new market by making the needed calculations for each PVHSs cash flow and estimating the time needed to repay the PVHS within the lenders' parameters. The income and net worth of the PVHS over its lifetime will be examined given warranties, insurance and form of financing as well as the homeowner (i.e. is the home insured, in a shaded area, facing a southern exposure etc.); ensuring that a PVHSs risk is properly allocated given technological constraints to geography and temperature.

From a social perspective various researchers, such as David Bollier[52] and Lester Brown[53], have found that consumer awareness plays a significant role in forming opinions of policymakers and utilities investing in incentive programs for renewable energy. The Natural Markets Institute in the US found that people in the Northeast region of the US care more about the use of renewable energy than people in the South, and that people in the West are more willing to spend USD 5 to 20 extra a month for renewable energy than those in the Midwest (Appendix 8). The high upfront costs of energy saving light bulbs discourage consumers to purchasing them although they have been proven to be cost effective. If the consumer is aware of their option to choose how the energy they consume is generated at no upfront cost then the demand for renewable energy could increase. By applying the two financial models developed in this thesis, loans and mortgages, to PVHSs and placing them into the commercial credit market the rate of renewable energy adoption could increase by assisting organizations interested in increasing their social responsibility efforts. The PVHS Loan and Mortgage are mechanisms that could guide European and American financial institutions towards assuming the responsibility of becoming clean energy producers, thereby making these economies an instrument towards the development of sustainable frameworks for social, political and economic systems.

4.1 Future Research

At the moment, the idea that the majority of the population could drive electric vehicles is unthinkable. The electricity required to support such a system would be beyond the generation capacity of most cities. It would be interesting to research how many PVHSs would be necessary in a given population (i.e. town or city) so that the widespread adoption of the electric car could become feasible.

For Portugal, current regulations do not allow residential solar home systems to sell more than 50% of their total consumption, even though Portugal is a net importer of electricity. For example, if my home in Lisbon, Portugal consumes 1,000 kWh of

[52] Bollier, David
[53] Brown, Lester

electricity in the month of January, my PVHS would only be able to sell 500 kWh of electricity onto the grid. There are similar regulations that dictate an individual must chose to either consume 100% of the solar power they produce or sell 100% of the production. In the United States the regulations vary by State but in general, individuals are allowed to consume or sell all the energy that they produce regardless of current consumption. It would be important to understand how the regulations will develop so that uniform PVHS loans can be securitized.

It would be provocative to study if the issuance of zero coupon bonds could work to capitalize PVHS loans and mortgages. To help mitigate new structure risk zero coupon bonds could be issued through credit unions using city and state specific raises. The bank would be able to raise the capital needed upfront without having to make any interest payments in the short term. The buyers of the zero coupon bonds could benefit from a tax exemption offered by the federal, state and city governments on income earned allowing for a lower coupon. A maturity of ten years with call dates that match the terms offered in the PVHS loans and mortgages would allow for greater certainty in repayments.

Finally, taking the work done here and applying a similar model to public, commercial and non-residential property would bring more clarity to the appropriate discount rate that should be charged and allow for better analysis by lenders. As these customers tend to consume larger quantities of electricity and provide employment inside communities decentralized solar PV might be an appropriate solution to some of their needs. The creation of a PV Commercial System Loan or a PV Community System Bond might work better than the models provided by solar developers.

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Appendix 1

Summary of LCOE Estimated from Various Sources in North America

Summary of LCOE estimated from various sources in North America.

Estimated LCOE ($/kWh)	Technology	Year	Plant specifications	Life	Financing and incentives	Location and solar resource
0.28–0.46	Solar PV (including tracking – 0.5%/year degr.)	2008	Residential ($7.5/W, CF 14–33%)	30	No subsidies (30 year mortgage, 100% financed, 6% IR, 6% DR, 35% TR)	Various cities in USA (1000–2500 kWh/m²/year)
0.20–0.32	Solar PV (including tracking – 0.5%/year degr.)	2008	Residential ($7.5/W, CF 14–33%)	30	With subsidies covering 30% initial cost (30 year mortgage, 100% financed, 6% IR, 6% DR, 35% TR)	Various cities in USA (1000–2500 kWh/m²/year)
0.15–0.80	Solar PV single axis	2009	25 MW (CF 27%, $4.55/Wp)	20	With and without tax benefits, and other incentives (merchant, IOU, POU)	CA, USA [California Energy Commission]
0.15–0.20	Solar PV-crystalline	2009	10 MW (CF 20–27%, $5/Wp)	20	Lower price includes incentives	USA
0.12–0.18	Solar PV-thin film	2009	10 MW (CF 20–23%, $4/Wp)	20	Lower price includes incentives	USA
0.16 (year 1)	Solar PV	2010	Large scale ($3.00/W, CF 21%)	20/100	20 year, 6% IR, no incentives or tax	USA Southwest
0.316–0.696	Solar PV	January 2011	2 kW ($7.51/W)	20	5% cost of capital (tax and incentives excluded)	Global [used 5.5 sun-hours and 2.5 sun-hours as high and low sites]
0.169–0.372	Solar PV	January 2011	500 kW ($3.98/W)	20	5% cost of capital (tax and incentives excluded)	Global [used 5.5 sun-hours and 2.5 sun-hours as high and low sites]
0.319–0.702	Solar PV	December 2010	2 kW ($7.61/W)	20	5% cost of capital (tax and incentives excluded)	Global [used 5.5 sun-hours and 2.5 sun-hours as high and low sites]
0.171–0.376	Solar PV	December 2010	500 kW ($4.07/W)	20	5% cost of capital (tax and incentives excluded)	Global [used 5.5 sun-hours and 2.5 sun-hours as high and low sites]
0.15	Solar PV (1%/year degr.)	2011	4.5 kW residential ($5/W, 10 year inverter life)	35	Not considered (SAM used)	Phoenix, USA
0.10	Solar PV (1%/year degr.)	2011	150 kW commercial ($4/W, 15 year inverter life)	35	Not considered (SAM used)	Phoenix, USA
0.12	Solar PV (1%/year degr.)	2011	12 MW single axis at tilt ($3.9/W, 15 year inverter life)	35	Not considered (SAM used)	Phoenix, USA
0.12	Solar PV (1%/year degr.)	2011	12 MW two-axis conc. ($4.3/W, 15 year inverter life)	35	Not considered (SAM used)	Phoenix, USA
0.32	Solar PV (1%/year degr.)	2005	4 kW (residential) ($8.47/W)	30	SAM (low values if unfinanced) effects of incentives, financing and tax considered	Phoenix, USA
0.18	Solar PV (1%/year degr.)	2005	150 kW (commercial) ($6.29/W)	30	SAM (low values if unfinanced)	Phoenix, USA
0.15–0.22	Solar PV (1%/year degr.)	2005	10 MW (utility scale) ($5.55/W)	30	SAM (low values if unfinanced)	Phoenix, USA
0.30	Solar PV (no degr.)	2007	Residential ($8.5/Wp)	30	Home equity loan/mortgage, 90% debt, 6% IR, 28% TR, 30 year loan with government incentives	USA (average – maps with state values given) (SAM used)
0.062	Solar PV	2006	3.51 MW, Utility Scale Pv fixed flat plate ($5.40/Wp, CF 19.5%)	30	No financing cost due to pay-as-go equity (IOU), includes tax credits	Springerville, Tucson, AZ, USA (1707 kWh/kW/year)
0.166	Solar PV	2003	5 MW ($4.16/W, CF 24%)	40	5% DR, no financing	USA
0.269	Solar PV	2003	5 MW ($4.16/W, CF 24%)	40	10% DR, no financing	USA
0.248	Solar PV	2010	Roof top PV (projected)	25	Weighted average cost of capital (6.4%)	AZ, USA (1700 kWh/kWp)
0.294	Solar PV	2008	Roof top PV ($5.2/W)	25	Weighted average cost of capital (6.4%)	AZ, USA (1700 kWh/kWp)

Continuation Appendix 1

Table 1 (*Continued*)

Estimated LCOE ($/kWh)	Technology	Year	Plant specifications	Life	Financing and incentives	Location and solar resource
0.40	Solar PV (1%/year degr.)	2009	Commerical ($6.7/W, CF 18%)	30	7% DR, no incentives (financing unclear)	USA
0.402–0.613	Solar PV (1%/year degr.)	2009	Rooftop ($7.20/Wp, CF 17%)	25	5%–10% DR, no incentives (financing unclear)	AZ, USA
0.309–0.499	Solar PV (1%/year degr.)	2009	80 MW ($6.7/Wp, CF 19%)	30	5%–10% DR, no incentives (financing unclear)	AZ, USA
0.561–0.860	Solar PV (1%/year degr.)	2009	Rooftop ($7.20/Wp, CF 12%)	25	5%–10% DR, no incentives (financing unclear)	NJ, USA
0.198	Concentrated solar PV (CSP)	2007	65 MW ($3.7/W, CF 22%)	30	7% DR, no subsidies (higher O&M than roof top) (financing unclear)	NV, USA
0.17–0.249	Concentrated solar PV (CSP)	2009	80 MW ($4.4/W, CF 29%)	30	5%–10% DR, no incentives (financing unclear)	USA
0.122–0.192	Concentrated solar PV (CSP)	2009	500 MW ($3.9/W, CF 23%)	30	5%–10% DR, no incentives (financing unclear)	USA
0.25–0.40	Solar PV (1–2%/year degr.)	2003	Utility Scale PV or residential ($6.20–9.50/W)	20	With and without subsidies, taxes, etc. (financing uncertain)	CA, USA (2000:kWh/m2/year)
0.49	Solar PV	2010	1 kW (CF 20%, $8.73/Wp)	25	Residential amortization	USA
0.138–0.206	Solar PV thin-film	2009	Large scale ≥20 MW (CF 18–27%, $3.7–4.0/W)	20?	With and without incentives, financing?	CA, USA
0.135–0.219	Solar PV crystalline single axis tracking	2009	Large scale ≥20 MW (CF 23–28%, $7.04–7.15/W)	20?	With and without incentives, financing?	CA, USA* done for different project zones
0.456	Solar PV (fixed flat plate)	2008	20 MW ($7.98/W, CF 26%)	30?	Weighted cost of captial after tax 5.9%, 15 year accelerated Depr?	USA
0.20–0.80	Solar PV	2007	Rooftop PV (2–5 kW)	20?	No subsidies	Worldwide range for 2500–1000 kWh/m^2 solar insolation -quoted from range of reports
0.20–0.50	Solar PV	2009	Rooftop (2–5 kW)	?	No subsidies/incentives	World average – quoted from range of reports
0.15–0.40	Solar PV	2008	Different applications (?)	?	Variable including taxes for USA (?)	Different locations, USA (?) see [58]
0.19	Solar PV	2007	Large scale	20	Independent power producer financing (no incentives)	Pacific north west, USA
0.22–0.24	Solar PV	2007	Small scale	20	Independent power producer financing (no incentives)	Pacific north west, USA
0.255	Solar PV (solar cell)	2008	5 MW ($5.782/W, CF 21%)	?	No incentives, financing for IPP	USA
0.20–0.50	Solar PV	2006	Varies at consumer level	20?	No incentives	Canada
0.20, 0.31	Solar PV	2004	2003 prices	?	DR 10% and 15% (Sandia Model, GenSim)	Chicago, USA
0.337–0.526	Solar PV -crystalline	2008 (2005 price)	5 MW ($6.31–%7.81/W, CF 15–25%)	20	?	?
0.392	Solar PV	2008	5 MW ($7/W, CF 20%)	?	?	Minera Escondida Limitada copper mine (off-grid) – South America
0.25	Solar PV	2010	2006 prices, includes storage	?	?	USA
0.15–0.78	Solar PV	2003	?	?	?	Canada, taken from US studies and converted to Canadian $

degr., degradation rate; CF, capacity factor; DR, discount rate; IR, interest rate; TR, tax rate; Depr, depreciation; IPP, independant power producer; IOU, investor-owned utilities; POU, publicly owned utilities meaning the rated system power (units displayed as referred in the sources); SAM, Solar Advisor Model (NREL).

Source: K. Branker, M.J.M. Pathak, J.M. Pearce, Renewable and Sustainable Energy Reviews (2011); 4470-4482

Appendix 2

<u>Retail Pricing for PVHS March 2011 – March 2012</u>

Solarbuzz Retail Pricing

Date: 07 January 2012

	unit	Mar 11	Apr 11	May 11	Jun 11	Jul 11	Aug 11	Sep 11	Oct 11	Nov 11	Dec 11	Jan 12	Feb 12	Mar 12
Module	US $/Wp (≥125 W)	3.19	3.12	3.11	3.10	3.02	2.84	2.65	2.6	2.49	2.43	2.42	2.3	2.29
	Euro €/Wp (≥125 W)	2.8	2.73	2.69	2.66	2.54	2.51	2.43	2.37	2.33	2.33	2.31	2.28	2.17
Inverter	US $/Continuous Watt	0.715	0.715	0.715	0.715	0.715	0.714	0.714	0.714	0.714	7.130	7.120	7.110	7.110
	Euro €/Continuous Watt	0.515	0.508	0.479	0.500	0.500	0.500	0.500	0.528	0.528	0.534	0.548	0.540	0.526
Battery	US $/Output Watt Hour	0.212	0.212	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213
	Euro €/Output Watt Hour	0.153	0.151	0.143	0.149	0.149	0.149	0.149	0.158	0.158	0.160	0.164	0.162	0.158
Charge Controller	US $/Amp	5.93	5.93	5.93	5.89	5.93	5.93	5.93	5.93	5.93	5.93	5.93	5.93	5.93
	Euro €/Amp	4.27	4.21	3.97	4.12	4.15	4.15	4.15	4.39	4.39	4.45	4.57	4.51	4.39
Solar Systems*	Residential c/kWh	30.53	30.42	30.34	30.31	30.08	29.84	29.53	29.38	29.25	29.2	29.14	29.00	28.91
	Commercial c/kWh	20.87	20.74	20.71	20.67	20.47	20.25	19.97	19.85	19.72	19.68	19.63	19.51	19.42
	Industrial c/kWh	16.27	16.20	16.14	16.11	15.95	15.79	15.56	15.47	15.37	15.34	15.31	15.21	15.15

These prices reflect the lowest price quoted on each company's website for the particular component and do not include sales tax.
Solarbuzz collects pricing information from companies worldwide. The current surveys include companies located in the US, Germany, UK, South Africa, Australia, Brazil, Bulgaria, France, Greece, Korea, Switzerland, Canada, and Japan.
Exchange rate conversions were made on the survey date.
This information may not represent actual pricing since actual pricing may be decided by discounts on multiple unit purchases and price matching of competitors.
Additional pricing detail, including factory gate pricing, manufacturing costs and manufacturer margins can be found in these Solarbuzz reports:
Solarbuzz Quarterly
Marketbuzz

* **Solar Systems** are indexes of grid-connected solar-system cost in price per kilowatt hour (after financing). These indexes are based on the Solarbuzz solar module retail price survey and draw exclusively on module prices in the high power band exclusively (> 125 Watts). They include full system integration and installation costs.

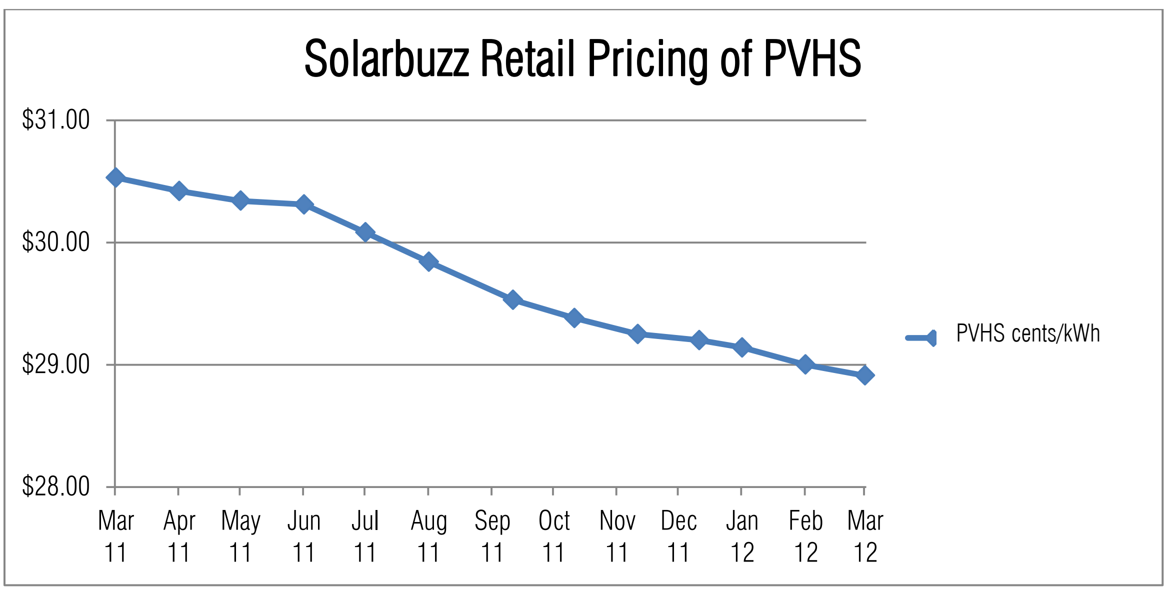
The **Residential Index** is based upon a standard 2 kilowatt peak system, retrofit roof-mounted solar system with a battery back-up.

The **Commercial Index** is based on a 50 kilowatt ground-mounted solar system. It provides distributed energy and excludes any back-up power.

The **Industrial Index** is based on a 500 kilowatt flat roof-mounted solar system, suitable on large buildings, without back-up power.

Prices are illustrative only and indicative of global rather than specific country, grid-connect markets. Prices for individual projects vary widely according to location and type of system. Indexes were rebased in October 2010.

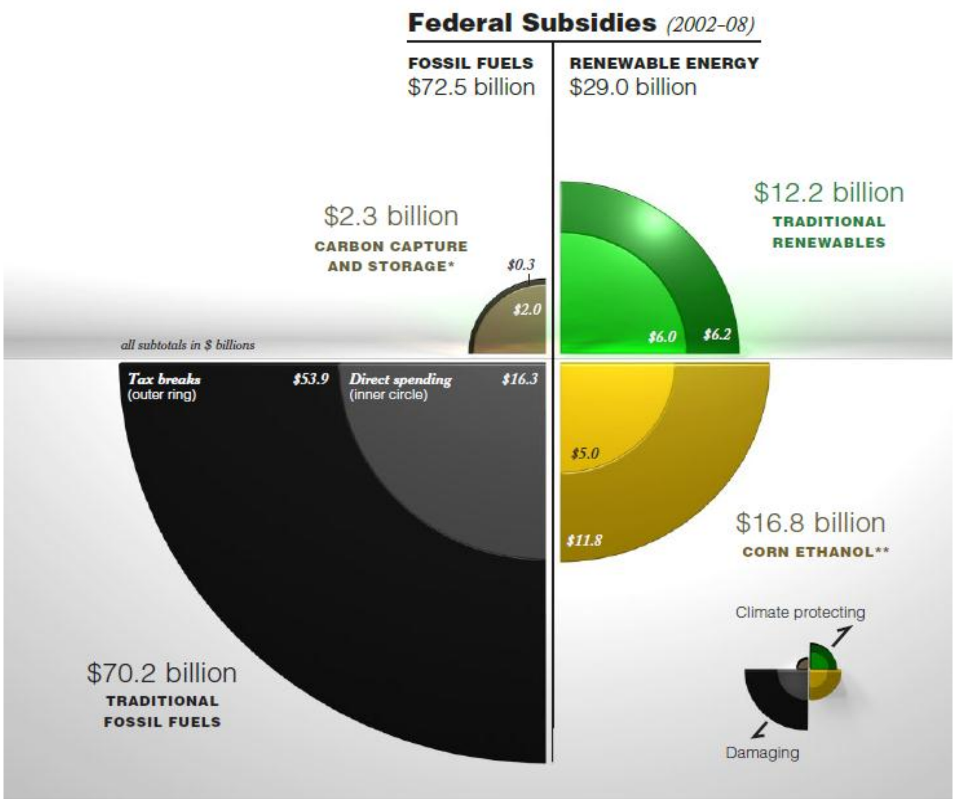
More information about methodology for this data can be found on our Retail Price Index Methodology page.



Source: Retail prices of components in a PVHS according to Solarbuzz website accessed December 8, 2012 (http://www.solarbuzz.com/)

Appendix 3

<u>Federal Subsidies to Energy in the US 2002-2008</u>



Sources: Internal Revenue Service, US DOE, US EIA, Congressional Joint Committee on Taxation, Office of Management and Budget, & US Department of Agriculture, via Environmental Law Institute
Infographic by Tommy McCall

Appendix 4

California Solar Initiative: San Diego, Residential Solar PV Rebates (2012)

Step	Statewide MW in Step	EPBB Payments (per Watt) Residential	EPBB Non-Residential Commercial	EPBB Non-Residential Government/ Non-Profit	PBI Payments (per kWh) Residential	PBI Non-Residential Commercial	PBI Non-Residential Government/ Non-Profit
1	50	n/a	n/a	n/a	n/a	n/a	n/a
2	70	$2.50	$2.50	$3.25	$0.39	$0.39	$0.50
3	100	$2.20	$2.20	$2.95	$0.34	$0.34	$0.46
4	130	$1.90	$1.90	$2.65	$0.26	$0.26	$0.37
5	160	$1.55	$1.55	$2.30	$0.22	$0.22	$0.32
6	190	$1.10	$1.10	$1.85	$0.15	$0.15	$0.26
7	215	$0.65	$0.65	$1.40	$0.09	$0.09	$0.19
8	250	$0.35	$0.35	$1.10	$0.05	$0.05	$0.15
9	285	$0.25	$0.25	$0.90	$0.03	$0.03	$0.12
10	350	$0.20	$0.20	$0.70	$0.03	$0.03	$0.10

Source: State of California, California Energy Commission & California Public Utilities Commission

Appendix 5

US Mortgage Market 1894

Mortgages Held by Different Investors.[2]	Stated.	Estimated.
171 Fire and Marine Insurance Companies licensed in Illinois, 1892	$41,937,522	
Other Fire and Marine Insurance Companies		$15,000,000
36 Life Insurance Companies licensed in Illinois in 1892	328,852,856	
Other Life Insurance Companies		10,000,000
Total net Assets of 5860 Building and Loan Associations, as Estimated by Mr. Carroll D. Wright	496,928,405	
Benefit and Aid Societies		10,000,000
643 Mutual Savings Banks	602,734,720	
416 Stock Savings Banks	112,097,856	
3191 State Banks	45,025,576	
1161 Private Banks	13,782,512	
168 Loan and Trust Companies	55,098,822	
Other Mortgage Companies	51,627,531	35,000,000
English Debenture Companies		100,000,000
Total	$1,748,085,800	$170,000,000
Grand Total		$1,918,085,800

"All these figures, except those estimated, have been taken from the Insurance Report of Illinois for 1892, from the Proceedings of the World's Congress of Local Building and Loan Associations, held in Chicago, 1893, and from the Report of the Comptroller of the Currency for 1892, vol. i. The figure of $51,627,531, for "other mortgage companies," has been obtained by taking first the amount of debentures as stated for the sixty-five companies referred to farther on, and deducting therefrom the amount of debentures issued by the trust companies reporting to the Comptroller of the Currency. This figure, therefore, represents a minimum stated amount of mortgages on hand to be added to the amount stated by the Comptroller."

Source: Frederiksen, D. M. "Mortgage Banking in America." Journal of Political Economy 2.2 (1894): p. 208

Appendix 6

Holders of Single-Family Residential Mortgages (Credit Exposures), 1960-2010

	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total ($ Billions)	**141.3**	**219.4**	**292.1**	**473.9**	**957.9**	**1526.2**	**2606.3**	**3445.4**	**5107.8**	**9382.4**	**10522.0**
Depository Institutions	94.9	157.7	207.2	347.8	642.1	785.2	1065.7	1183.6	1668.5	2965.6	2956.1
Commercial Banks	19.2	30.4	42.3	77.0	159.0	212.5	432.8	650.2	969.9	1792.1	2204.8
Thrifts	74.8	125.8	164.0	268.8	478.5	561.7	600.2	482.4	594.2	953.8	430.5
Credit Unions	0.9	1.4	0.8	2.0	4.6	11.1	32.7	51.0	104.4	219.7	320.8
Fannie Mae, Freddie Mac & Ginnie Mae	2.9	2.6	18.1	56.3	164.9	472.1	1110.5	1752.9	2635.2	3900.3	5770.3
Government-sponsored Enterprises	2.9	2.5	15.5	30.9	57.8	111.6	119.5	209.5	209.6	453.9	4701.5
Agency- and GSE-backed mortgage pools	0.0	0.1	2.5	25.3	107.1	360.5	991.1	1543.4	2425.6	3446.4	1068.8
ABS Issuers	0.0	0.0	0.0	0.0	0.0	24.0	55.0	193.8	385.5	1621.9	1277.2
Finance Companies	1.4	3.8	5.8	8.5	22.3	38.2	80.2	66.5	186.9	489.8	280.6
All others (residual)	42.1	55.3	61.1	61.4	128.6	206.6	294.8	248.7	231.7	404.8	237.8
% Distribution											
Depository Institutions	67.1%	71.9%	70.9%	73.4%	67.0%	51.4%	40.9%	34.4%	32.7%	31.6%	28.1%
Commercial Banks	13.6%	13.9%	14.5%	16.3%	16.6%	13.9%	16.6%	18.9%	19.0%	19.1%	21.0%
Thrifts	52.9%	57.4%	56.2%	56.7%	50.0%	36.8%	23.0%	14.0%	11.6%	10.2%	4.1%
Credit Unions	0.6%	0.6%	0.3%	0.4%	0.5%	0.7%	1.3%	1.5%	2.0%	2.3%	3.0%
Fannie Mae, Freddie Mac & Ginnie Mae	2.1%	1.2%	6.2%	11.9%	17.2%	30.9%	42.6%	50.9%	51.6%	41.6%	54.8%
Government-sponsored Enterprises	2.1%	1.1%	5.3%	6.5%	6.0%	7.3%	4.6%	6.1%	4.1%	4.8%	44.7%
Agency- and GSE-backed mortgage pools	0.0%	0.0%	0.9%	5.3%	11.2%	23.6%	38.0%	44.8%	47.5%	36.7%	10.2%
ABS Issuers	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	2.1%	5.6%	7.5%	17.3%	12.1%
Finance Companies	1.0%	1.7%	2.0%	1.8%	2.3%	2.5%	3.1%	1.9%	3.7%	5.2%	2.7%
All others (residual)	29.8%	25.2%	20.9%	13.0%	13.4%	13.5%	11.3%	7.2%	4.5%	4.3%	2.3%

Source: Federal Reserve Flow of Funds Table L. 218 data retrieved on December 8, 2012 (http://www.federalreserve.gov/releases/z1/current/data.htm)

Appendix 7

SAM Output for Lisbon, Portugal PVHS

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Energy (kWh)	0	5,997	5,949	5,902	5,855	5,808	5,761	5,715	5,670	5,624	5,579	5,535	5,490	5,446	5,403	5,360
Energy Value ($)	0	1,721.28	1,750.19	1,779.60	1,809.49	1,839.89	1,870.80	1,902.23	1,934.19	1,966.68	1,999.73	2,033.32	2,067.48	2,102.21	2,137.53	2,173.44
Operating Expenses																
Fixed O&M Annual	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fixed O&M	0	80	82	84.05	86.15	88.31	90.51	92.78	95.09	97.47	99.91	102.41	104.97	107.59	110.28	113.04
Variable O&M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Insurance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Property Assessed Value	0	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240
Property Taxes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Net Salvage Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operating Costs	0	80	82	84.05	86.15	88.31	90.51	92.78	95.09	97.47	99.91	102.41	104.97	107.59	110.28	113.04
Deductible Expenses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Financing																
Debt Balance	0	-20,240	-19,893.93	-19,533.16	-19,157.05	-18,764.95	-18,356.19	-17,930.06	-17,485.82	-17,022.70	-16,539.90	-16,036.57	-15,511.86	-14,964.85	-14,394.58	-13,800.09
Debt Interest Payment	0	860.2	845.49	830.16	814.17	797.51	780.14	762.03	743.15	723.46	702.95	681.55	659.25	636.01	611.77	586.5
Debt Repayment	0	346.07	360.78	376.11	392.09	408.76	426.13	444.24	463.12	482.8	503.32	524.71	547.01	570.26	594.5	619.76
Debt Total Payment	0	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27
PVHS Savings	0	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7
PVHS Income	0	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57
PVHS savings - Debt Repayment	0	16.63	1.92	-13.41	-29.39	-46.06	-63.43	-81.54	-100.42	-120.1	-140.62	-162.01	-184.31	-207.56	-231.8	-257.06
PVHS income - Debt Interest Payment	0	0.37	15.08	30.41	46.40	63.06	80.43	98.54	117.42	137.11	157.62	179.02	201.32	224.56	248.80	274.07
After Tax Cost	0	-1,286.27	-1,288.27	-1,290.32	-1,292.42	-1,294.57	-1,296.78	-1,299.04	-1,301.36	-1,303.74	-1,306.18	-1,308.68	-1,311.24	-1,313.86	-1,316.55	-1,319.31
After Tax Cashflow	0	435.01	461.92	489.28	517.07	545.32	574.02	603.19	632.83	662.94	693.55	724.65	756.24	788.35	820.98	854.14
Payback	-20,240	1,641.28	1,668.19	1,695.55	1,723.34	1,751.59	1,780.29	1,809.46	1,839.10	1,869.21	1,899.82	1,930.91	1,962.51	1,994.62	2,027.25	2,060.40
Cumulative payback	-20,240	-18,598.72	-16,930.53	-15,234.98	-13,511.64	-11,760.05	-9,979.76	-8,170.30	-6,331.21	-4,462	-2,562.18	-631.27	1,331.25	3,325.87	5,353.12	7,413.52

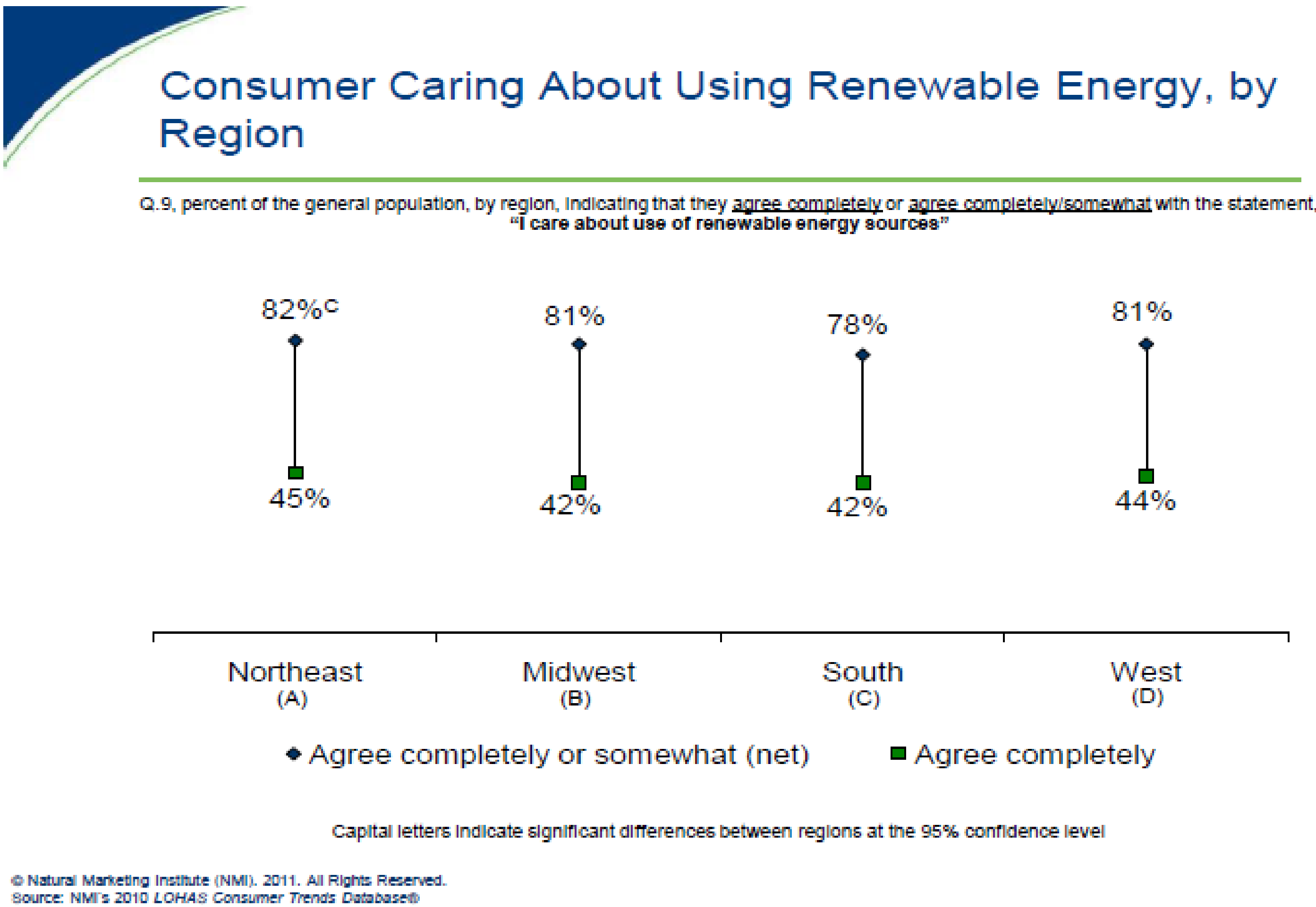
Continuation of Appendix 7

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Energy (kWh)	5,317	5,274	5,232	5,190	5,149	5,107	5,067	5,026	4,986	4,946	4,906	4,867	4,828	4,790	4,751
Energy Value ($)	2,209.96	2,247.08	2,284.83	2,323.22	2,362.25	2,401.93	2,442.29	2,483.32	2,525.04	2,567.46	2,610.59	2,654.45	2,699.04	2,744.39	2,790.49
Operating Expenses															
Fixed O&M Annual	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fixed O&M	115.86	118.76	121.73	124.77	127.89	131.09	134.37	137.73	141.17	144.7	148.32	152.02	155.82	159.72	163.71
Variable O&M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Insurance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Property Assessed Value	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240	20,240
Property Taxes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Net Salvage Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operating Costs	115.86	118.76	121.73	124.77	127.89	131.09	134.37	137.73	141.17	144.7	148.32	152.02	155.82	159.72	163.71
Deductible Expenses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Financing															
Debt Balance	-13,180.32	-12,534.22	-11,860.65	-11,158.46	-10,426.43	-9,663.28	-8,867.70	-8,038.31	-7,173.67	-6,272.28	-5,332.59	-4,352.95	-3,331.68	-2,267.01	-1,157.09
Debt Interest Payment	560.16	532.7	504.08	474.23	443.12	410.69	376.88	341.63	304.88	266.57	226.63	185	141.6	96.35	49.18
Debt Repayment	646.1	673.56	702.19	732.03	763.15	795.58	829.39	864.64	901.39	939.7	979.63	1,021.27	1,064.67	1,109.92	1,157.09
Debt Total Payment	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27	1,206.27
PVHS Savings	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7	362.7
PVHS Income	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57	860.57
PVHS savings - Debt Repayment	-283.4	-310.86	-339.49	-369.33	-400.45	-432.88	-466.69	-501.94	-538.69	-577	-616.93	-658.57	-701.97	-747.22	-794.39
PVHS income - Debt Interest Payment	300.41	327.87	356.49	386.34	417.45	449.88	483.69	518.94	555.69	594.00	633.94	675.57	718.97	764.22	811.39
After Tax Cost	-1,322.13	-1,325.03	-1,328	-1,331.04	-1,334.16	-1,337.36	-1,340.64	-1,343.99	-1,347.44	-1,350.97	-1,354.58	-1,358.29	-1,362.09	-1,365.99	-1,369.98
After Tax Cashflow	887.82	922.05	956.84	992.18	1,028.09	1,064.58	1,101.65	1,139.32	1,177.60	1,216.49	1,256.01	1,296.16	1,336.95	1,378.40	1,420.51
Payback	2,094.09	2,128.32	2,163.10	2,198.45	2,234.36	2,270.85	2,307.92	2,345.59	2,383.87	2,422.76	2,462.28	2,502.43	2,543.22	2,584.67	2,626.78
Cumulative payback	9,507.62	11,635.94	13,799.04	15,997.49	18,231.85	20,502.69	22,810.61	25,156.21	27,540.07	29,962.83	32,425.11	34,927.54	37,470.76	40,055.43	42,682.21

Source: SAM Computer Modeling Software

Appendix 8

Consumers Caring About Renewable Energy, by Region



Source: Bird, Lori, Summer Jenny, and Gywnne Rogers. "Consumer Attitudes About Renewable Energy: Trends and Regional Differences." Lifestyles of Health and Sustainability Consumer Trends Database. Natural Marketing Institute, accessed on December 8, 2012: (http://www.nmisolutions.com/index.php/syndicated-data/nmis-proprietary-databases/lohas-consumer-trends-database)

Appendix 9

Efacec Renewables Simulation for 4 kW PVHS in Lisbon, Portugal:

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Grid-Connected System: Simulation parameters

Project :	**David Pereira**			
Geographical Site	**Lisboa**		**Country**	**Portugal**
Situation	Latitude	38.7°N	Longitude	9.1°W
Time defined as	Legal Time	Time zone UT+0	Altitude	56 m
	Albedo	0.20		
Meteo data :	Lisboa, Synthetic Hourly data			
Simulation variant :	**Lisboa_10.8kW_Renesola235_TRP10TL**			
	Simulation date	12/12/12 12h16		

Simulation parameters

Collector Plane Orientation	Tilt	30°	Azimuth	0°
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module Si-poly	Model	**CSUN 245-60P**		
	Manufacturer	China Sunergy		
Number of PV modules	In series	10 modules	In parallel	2 strings
Total number of PV modules	Nb. modules	20	Unit Nom. Power	245 Wp
Array global power	Nominal (STC)	**4900 Wp**	At operating cond.	4422 Wp (50°C)
Array operating characteristics (50°C)	U mpp	273 V	I mpp	16 A
Total area	Module area	**32.5 m²**		
Inverter	Model	**Sunny Boy SB 4000 TL-20**		
	Manufacturer	SMA		
Characteristics	Operating Voltage	175-440 V	Unit Nom. Power	4.00 kW AC

PV Array loss factors

Thermal Loss factor	Uc (const)	29.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (G=800 W/m², Tamb=20°C, Wind=1 m/s.)			NOCT	45 °C
Wiring Ohmic Loss	Global array res.	282 mOhm	Loss Fraction	1.5 % at STC
Array Soiling Losses			Loss Fraction	1.5 %
Module Quality Loss			Loss Fraction	0.1 %
Module Mismatch Losses			Loss Fraction	2.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Parameter	0.05

User's needs : Unlimited load (grid)

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Grid-Connected System: Main results

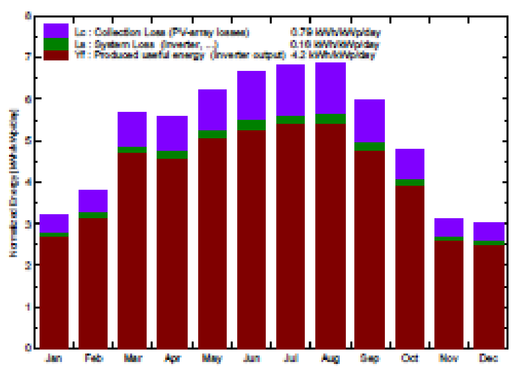
Project : **David Pereira**

Simulation variant : **Lisboa_10.8kW_Renesola235_TRP10TL**

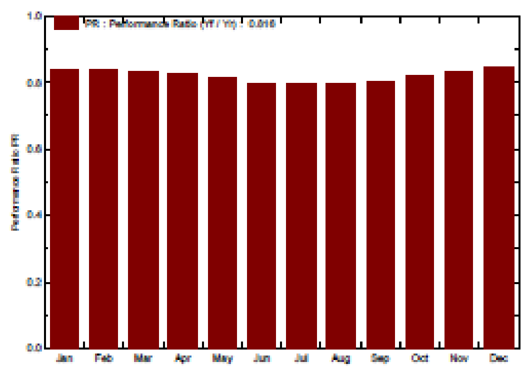
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	CSUN 245-60P	Pnom	245 Wp
PV Array	Nb. of modules	20	Pnom total	**4900 Wp**
Inverter	Model	Sunny Boy SB 4000 TL-20	Pnom	4000 W ac
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	Produced Energy	7513 kWh/year	Specific prod.	1533 kWh/kWp/year
	Performance Ratio PR	81.6 %		

Normalized productions (per installed kWp): Nominal power 4900 Wp



Performance Ratio PR



Lisboa_10.8kW_Renesola235_TRP10TL

Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	EffArrR	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	%	%
January	66.2	11.20	99.6	96.6	426.2	410.5	13.18	12.69
February	78.6	12.10	106.4	103.4	452.7	436.0	13.10	12.61
March	144.3	14.40	175.7	170.6	743.5	717.6	13.03	12.58
April	158.4	15.20	167.3	162.3	703.1	677.6	12.94	12.47
May	199.4	17.40	192.7	186.4	798.6	769.8	12.76	12.30
June	216.0	21.00	199.5	192.8	809.5	779.4	12.49	12.03
July	224.7	22.20	211.7	205.2	855.3	823.4	12.44	11.98
August	206.8	22.70	212.0	205.9	859.1	827.4	12.48	12.02
September	155.5	21.20	179.2	174.1	733.0	706.0	12.60	12.13
October	113.1	18.10	148.4	144.2	619.0	596.9	12.85	12.39
November	64.8	14.00	93.8	91.0	397.9	383.3	13.06	12.58
December	58.0	11.80	93.0	90.3	399.9	385.2	13.24	12.75
Year	1685.8	16.80	1879.4	1822.9	7797.7	7513.1	12.78	12.31

Legends: GlobHor Horizontal global irradiation; T Amb Ambient Temperature; EArray Effective energy at the output of the array; E_Grid Energy injected into grid

Continuation Appendix 9

efacec Renewables

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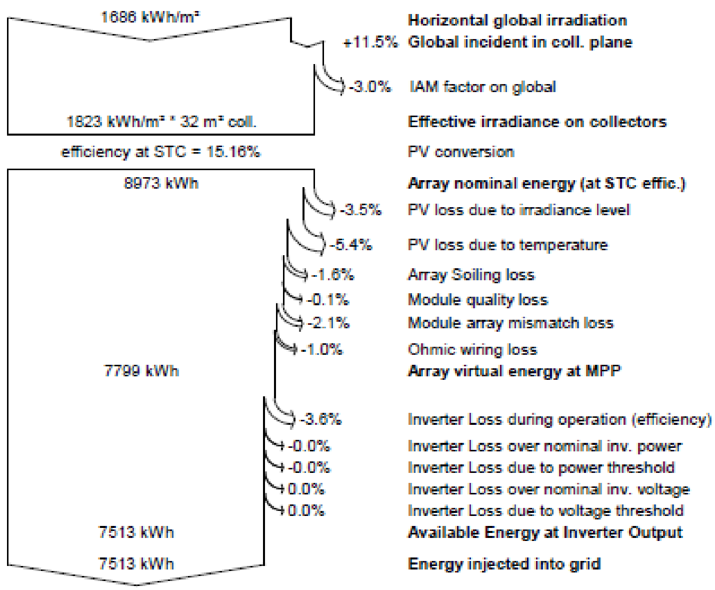
Grid-Connected System: Loss diagram

Project : **David Pereira**

Simulation variant : **Lisboa_10.8kW_Renesola235_TRP10TL**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	CSUN 245-60P	Pnom	245 Wp
PV Array	Nb. of modules	20	Pnom total	**4900 Wp**
Inverter	Model	Sunny Boy SB 4000 TL-20	Pnom	4000 W ac
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



Source: Efacec Renewables; Maia, Portugal. December 12, 2012.

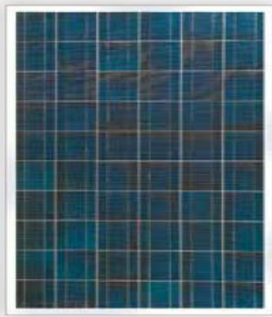
*Please note the estimate from Efacec states that the PVHS could produce 7,513 kWh/year which is 1,516 kWh/year greater than the kWh/year used in this works estimates.

Appendix 10

Components of the PVHS Used for SAM and Efacec Renewables Simulations

Poly Mono

CSUN
energy for the future



Standard Solar Product

CSUN250-60P

Module efficiency
15.40%

Highest power output
250W

Material & Workmanship warranty
10year

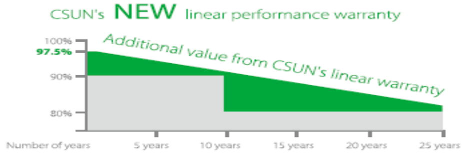
Linear power output warranty
25year

Powerguard insurance global coverage

PowerGuard
SPECIALTY INSURANCE SERVICES

- Industry leading conversion efficiency
- Positive tolerance offer
- Passed salt mist corrosion testing and ammonia corrosion testing
- Certificated to withstand Wind (2400Pa) and Snow load (7200Pa)
- Excellent performance under weak light condition
- Good TC performance enables better output in the tropical zone

CSUN's NEW linear performance warranty



Within the first year, the output power shall not be less than 97.5% of the minimum output power in CSUN's product datasheet, thereafter the loss of output power shall not exceed 0.7% per year, ending with 80.7% in the 25th year.

- China Sunergy (Nanjing) Co., Ltd. (NASDAQ: CSUN), established in 2004, is a hi-tech corporation with its core business in R&D, manufacturing, and sale of high efficiency silicon based solar cells and modules.
- As one of the leading PV enterprises in the world, CSUN has delivered more than 1GW solar products, to residential, commercial, utility and off-grid projects all around the world.
- Through strict selection of raw materials, stringent quality control and rigorous test in state of the art facilities in Nanjing and Shanghai, CSUN has always committed to higher efficiency, more stable and better cost performance products.

* Note: All specifications, warranties, certifications about module of "CSUN" series also apply to that of "SST".

www.chinasunergy.com

Continuation Appendix 10

Specifications

Type	250-60P	245-60P	240-60P	235-60P	230-60P
	Electrical typical data				
Pmpp [W]	250	245	240	235	230
Voc [V]	37.3	37.1	36.9	36.8	36.7
Isc [A]	8.81	8.74	8.67	8.59	8.52
Vmpp [V]	29.9	29.7	29.6	29.5	29.4
Impp [A]	8.36	8.25	8.11	7.97	7.83
Practical module efficiency	17.12%	16.78%	16.44%	16.10%	15.75%
Module efficiency	15.40%	15.09%	14.78%	14.47%	14.17%
Maximum system voltage [V]	1000				
Voltage temperature coefficient	-0.292%/K				
Current temperature coefficient	+0.045%/K				
Power temperature coefficient	-0.408%/K				
Series fuse rating [A]	20				
Cells	6×10 pieces polycrystalline solar cells series strings (156mm×156mm)				
Junction box	with 6 bypass diodes				
Cable	length 900 mm, 1×4 mm²				
Front glass	White toughened safety glass, 3.2 mm				
Cell encapsulation	EVA (Ethylene-Vinyl-Acetate)				
Back sheet	composite film				
Frame	Anodized aluminum profile				
Dimensions	1640×990×40mm (L×W×H)				
Maximum surface load capacity	7,200 Pa				
Hail	maximum diameter of 25 mm with impact speed of 23 m·s⁻¹				
Temperature range	– 40 °C to + 85 °C				
Weight	19.1kg				

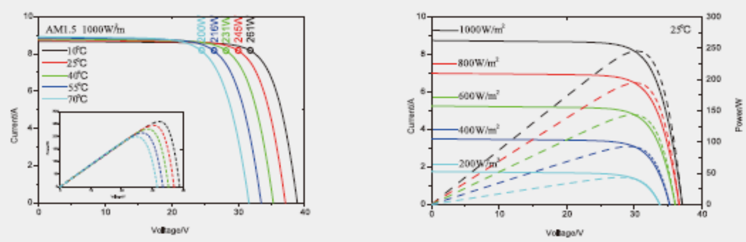
The electrical data relates to standard test conditions (STC): 1,000 W/m²; AM 1,5; 25°C.
Performance deviation of Pmpp: 0-5W. performance deviation of Voc[V],Isc[A],Vmpp [V] and Impp [A]: ±10%.
Certified in accordance with IEC 61215, IEC 61730-1/2 and UL 1703.

Operating Condition & Packaging

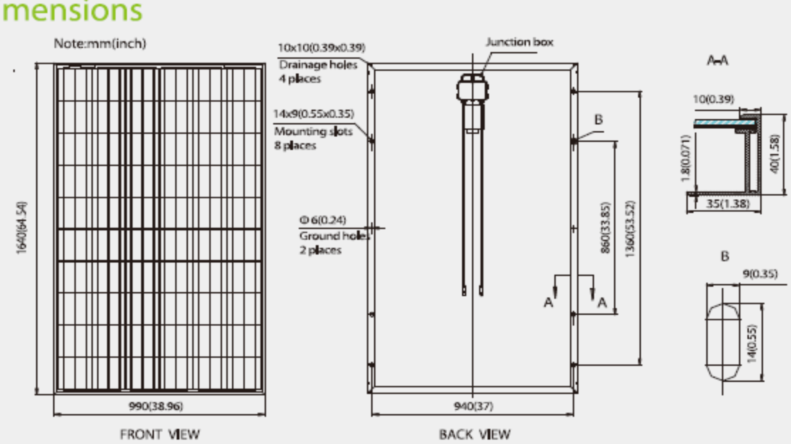
Maximum surface load capacity	tested up to 7,200 Pa according to IEC 61215
Hail	maximum diameter of 25 mm(1inch) with impact speed of 23 m/s (51.2mph)
Temperature range	– 40 °C to + 85 °C

Dimensions(LxWxH)	Container 20'	Container20'HC	Container40'	Container40'HC
1640x990x40mm	300	324	700	756

IV-Curves



Dimensions



SUNNY TRIPOWER
8000TL / 10000TL / 12000TL / 15000TL / 17000TL

Economical

- Maximum efficiency of 98.2 %
- SMA OptiTrac Global Peak MPP tracking for best MPP tracking efficiency
- Bluetooth® communication

Reliable

- Triple protection with Optiprotect:
- Electronic string fuse
- Self-learning string failure detection
- DC surge arrester (Type II) can be integrated

Flexible

- DC input voltage up to 1000 V
- Integrated grid management functions
- Custom plant design with Optiflex

Simple

- Three-phase feed-in
- Cable connection without tools
- SUNCLIX DC plug-in system
- Easily accessible connection area

SUNNY TRIPOWER
8000TL / 10000TL / 12000TL / 15000TL / 17000TL

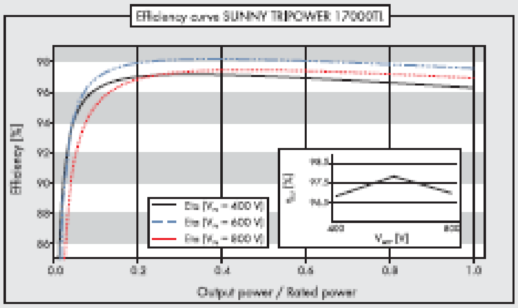
The three-phase inverter for easy plant design

Full of pioneering technology: highly flexible plant design with the three-phase Sunny Tripower inverter. Thanks to Optiflex technology, two MPP inputs and a broad input voltage range, it is suited to almost any module configuration. It meets any requirement such as reactive power supply, grid support thus reliably participating in grid management. The safety concept Optiprotect with its self-learning string-failure detection, electronic string fuse and integrable DC surge arrester type II, ensures maximum availability.

Continuation Appendix 10

SUNNY TRIPOWER
8000TL / 10000TL / 12000TL / 15000TL / 17000TL

Technical Data	Sunny Tripower 8000TL	Sunny Tripower 10000TL
Input (DC)		
Max. DC power (@ cos φ=1)	8200 W	10200 W
Max. input voltage	1000 V	1000 V
MPP voltage range / rated input voltage	320 V – 800 V / 600 V	320 V – 800 V / 600 V
Min. input voltage / initial input voltage	150 V / 188 V	150 V / 188 V
Max. input current input A / input B	22 A / 11 A	22 A / 11 A
Max. input current per string input A* / input B*	33 A / 12.5 A	33 A / 12.5 A
Number of independent MPP inputs / strings per MPP input	2 / A:4; B:1	2 / A:4; B:1
Output (AC)		
Rated power (@ 230 V, 50 Hz)	8000 W	10000 W
Max. apparent AC power	8000 VA	10000 VA
Nominal AC voltage	3 / N / PE; 220 / 380 V 3 / N / PE; 230 / 400 V 3 / N / PE; 240 / 415 V	3 / N / PE; 220 / 380 V 3 / N / PE; 230 / 400 V 3 / N / PE; 240 / 415 V
Nominal AC voltage range	160 V – 280 V	160 V – 280 V
AC power frequency / range	50 Hz, 60 Hz / −6 Hz ... +5 Hz	50 Hz, 60 Hz / −6 Hz ... +5 Hz
Rated grid frequency / rated grid voltage	50 Hz / 230 V	50 Hz / 230 V
Max. output current	16 A	16 A
Power factor at rated power	1	1
Adjustable displacement factor	0.8 overexcited... 0.8 underexcited	0.8 overexcited... 0.8 underexcited
Phase conductors / connection phases	3 / 3	3 / 3
Efficiency		
Max. efficiency / European efficiency	98.1 % / 97.5 %	98.1 % / 97.7 %
Protection		
Input-side disconnection device	●	●
Ground-fault monitoring / grid monitoring	● / ●	● / ●
DC surge arrester Type II, can be integrated	○	○
DC reverse-polarity protection / AC short-circuit current capability / galvanically isolated	● / ● / –	● / ● / –
All-pole sensitive residual current monitoring unit	●	●
Protection class (according to IEC 62103) / overvoltage category (according to IEC 60664-1)	I / III	I / III
General Data		
Dimensions (W / H / D)	665 / 690 / 265 mm (26.2 / 27.2 / 10.4 in)	665 / 690 / 265 mm (26.2 / 27.2 / 10.4 in)
Weight	59 kg / 130.07 lb	59 kg / 130.07 lb
Operating temperature range	−25 °C...+60 °C/−13 °F...+140 °F	−25 °C...+60 °C/−13 °F...+140 °F
Noise emission (typical)	51 dB(A)	51 dB(A)
Self-consumption at night	1 W	1 W
Topology / cooling concept	Transformerless / OptiCool	Transformerless / OptiCool
Degree of protection / degree of protection of connection area (according to IEC 60529)	IP65 / IP54	IP65 / IP54
Climatic category (according to IEC 60721-3-4)	4K4H	4K4H
Maximum permissible value for relative humidity (non-condensing)	100 %	100 %
Features		
DC terminal	SUNCLIX	SUNCLIX
AC terminal	Spring-type terminal	Spring-type terminal
Display	Graphic	Graphic
Interface: RS485 / Bluetooth / Multi-function relay	○ / ● / ●	○ / ● / ●
Warranty: 5 / 10 / 15 / 20 / 25 years	● / ○ / ○ / ○ / ○	● / ○ / ○ / ○ / ○
Certificates and approvals (more available on request)	CE, VDE0126-1-1, RD 661/2007, PPC, AS 4777, EN 50438[1], C10/11, PPDS, IEC 61727, ENEL-Guida, UTE C15-712-1, G59/2, VDE-AR-N 4105, BDEW 2008, RD1699, CEI 0-21[2]	
Type designation	STP 8000TL-10	STP 10000TL-10



Accessories

RS485 interface
DM-485CB-10

DC surge arrester
(Type II), input A
DCSPD KIT1-10

DC surge arrester
(Type II), inputs A and B
DCSPD KIT2-10

[1] Does not apply to all national deviations of EN 50438
[2] Planned certificates and approvals
[*] To be observed in case of a short circuit in the electronic string fuse

● Standard features ○ Optional features – Not available
Data at nominal conditions

Sunny Tripower 12000TL	Sunny Tripower 15000TL	Sunny Tripower 17000TL
12250 W	15340 W	17410 W
1000 V	1000 V	1000 V
380 V - 800 V / 600 V	360 V - 800 V / 600 V	400 V - 800 V / 600 V
150 V / 188 V	150 V / 188 V	150 V / 188 V
22 A / 11 A	33 A / 11 A	33 A / 11 A
33 A / 12.5 A	40 A / 12.5 A	40 A / 12.5 A
2 / A:4; B:1	2 / A:5; B:1	2 / A:5; B:1
12000 W	15000 W	17000 W
12000 VA	15000 VA	17000 VA
3 / N / PE; 220 / 380 V 3 / N / PE; 230 / 400 V 3 / N / PE; 240 / 415 V	3 / N / PE; 220 / 380 V 3 / N / PE; 230 / 400 V 3 / N / PE; 240 / 415 V	3 / N / PE; 220 / 380 V 3 / N / PE; 230 / 400 V 3 / N / PE; 240 / 415 V
160 V - 280 V	160 V - 280 V	160 V - 280 V
50 Hz, 60 Hz / −6 Hz ... +5 Hz	50 Hz, 60 Hz / −6 Hz ... +5 Hz	50 Hz, 60 Hz / −6 Hz ... +5 Hz
50 Hz / 230 V	50 Hz / 230 V	50 Hz / 230 V
19.2 A	24 A	24.6 A
1	1	1
0.8 overexcited... 0.8 underexcited	0.8 overexcited... 0.8 underexcited	0.8 overexcited... 0.8 underexcited
3 / 3	3 / 3	3 / 3
98.1 % / 97.7 %	98.2 % / 97.8 %	98.2 % / 97.8 %
●	●	●
● / ●	● / ●	● / ●
○	○	○
● / ● / –	● / ● / –	● / ● / –
●	●	●
I / III	I / III	I / III
665 / 690 / 265 mm (26.2 / 27.2 / 10.4 in)	665 / 690 / 265 mm (26.2 / 27.2 / 10.4 in)	665 / 690 / 265 mm (26.2 / 27.2 / 10.4 in)
59 kg / 130.07 lb	59 kg / 130.07 lb	59 kg / 130.07 lb
−25 °C...+60 °C / −13 °F...+140 °F	−25 °C...+60 °C / −13 °F...+140 °F	−25 °C...+60 °C / −13 °F...+140 °F
51 dB(A)	51 dB(A)	51 dB(A)
1 W	1 W	1 W
Transformerless / OptiCool	Transformerless / OptiCool	Transformerless / OptiCool
IP65 / IP54	IP65 / IP54	IP65 / IP54
4K4H	4K4H	4K4H
100 %	100 %	100 %
SUNCLIX	SUNCLIX	SUNCLIX
Spring-type terminal	Spring-type terminal	Spring-type terminal
Graphic	Graphic	Graphic
○ / ● / ●	○ / ● / ●	○ / ● / ●
● / ○ / ○ / ○ / ○	● / ○ / ○ / ○ / ○	● / ○ / ○ / ○ / ○
CE, VDE0126-1-1, RD 661/2007, PPC, AS 4777, EN 50438[1], C10/11, PPDS, IEC 61727, ENEL-Guida, UTE C15-712-1, G59/2, VDE-AR-N 4105, BDEW 2008, RD1699, CEI 0-21[2]		
STP 12000TL-10	STP 15000TL-10	STP 17000TL-10

Matrix

Business Models for Solar PV Systems	Incentives	Hinderance	Control of Asset	Residual Claims
Energy Efficent Mortgages	◦ property valuation rises ◦ payment rate is constant ◦ no upfront cost	◦ energy audit ◦ the lender determines which energy improvements apply	Homeowner	Homeowner
Customer Solar Lease	◦ no upfront cost to lesseee ◦ payment rate is constant	◦ no benefits afforded to lesseee ◦ lessor has tax free income ◦ poor maintenace as payments are fixed	Solar Developer	Solar Developer
Commercial PPA	◦ all benefits afforded ◦ tax free income (ITC)	◦ up-front cost ◦ Solar Developer must O&M ◦ sale of property issues ◦ rate changes	Property owner	Business Owner
Residential PPA	◦ all benefits afforded ◦ tax free income (ITC)	◦ up-front cost ◦ Homeowner must O&M ◦ sale of home issues ◦ rates changes	Homeowner	Homeowner
Solar Developer PPA	◦ no up-front cost ◦ all benefits afforded ◦ tax free income (ITC) ◦ low interest gov't bonds	◦ Solar Developer must O&M ◦ sale of home issues ◦ political risk	Solar Developer	Solar Developer
Property Assessed Clean Energy Programs (PACE)	◦ all benefits afforded ◦ tax free income (ITC) ◦ low interest gov't bonds ◦ property value rises ◦ easy transfer of property	◦ Homeowner must O&M ◦ rate changes ◦ political risk	Property Owner	◦ Property Owner ◦ Government
Energy Saving Performance Contracts (UK)	◦ no up-front cost ◦ energy savings	◦ sale of home issues ◦ no FIT	Solar Developer	Solar Developer
Feed In Tariffs (UK)	◦ easy transfer of property ◦ energy savings ◦ FIT	◦ up-front cost	Homeowner	Homeowner
Equity Solar Programs	◦ no roof needed ◦ can sell home in utility area ◦ all benefits afforded ◦ No O&M on PV system	◦ up-front cost	Shareholders	Shareholders
Solar Brokers	◦ economies of scale ◦ expertice	◦ higher up-front cost	Homeowner	◦ Utility ◦ Solar Developer ◦ Home Owner
PVHS Loan	◦ all benefits afforded ◦ tax free income (ITC) ◦ constant payment rate ◦ property value rises ◦ easy transfer of property ◦ SEFA ◦ low interest financing	◦ Homeowner must O&M ◦ rate changes ◦ political risk	Homeowner	Bank
PVHS Mortgage	◦ all benefits afforded ◦ tax free income (ITC) ◦ constant payment rate ◦ property value rises ◦ easy transfer of property ◦ SEFA ◦ low interest financing	◦ Homeowner must O&M ◦ rate changes ◦ political risk	Homeowner	Bank

Matrix Continued

Performance Criteria	Pays for Power output	Earns Power Output	Pays Regardless of Power Produced	Upfront Capital Cost	Design, Finance, Management, Construction & Maintainence of PV	Duration
constant payments on mortgage		X	X	Bank	Homeowner	10-30 years
constant payments on lease but lesseee can benefit from overproduction of electricty	X	X	X	Solar Developer	Solar Developer	year to year (random)
payments earned on electricity output		X		Property Owner	Property Owner	10 years
payments earned on electricity output		X		Homeowner	Homeowner	10 years
payments based on electricity output	X			Solar Developer	Solar Developer	10-30 years
constant payments on assessment		X	X	Property Owner	Property Owner	10-30 years
constant payments based on electricity output		X	X	Solar Developer	Solar Developer	25 years
constant payments based on electricity output		X	X	Homeowner	Homeowner	25 years
one time upfront payment		X		Equity Owner	Solar Developer	year to year (random)
one time upfront commission payment to solar broker		X		Homeowner	Solar Developer	none
constant payment on loan	X	X		Bank	Homeowner	10-30 years
payments based on electricity output (savings)	X	X		Bank	Homeowner	30 years